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JOS. M. WILSON, President, in the chair.

Paper of the Evening:

THE CARBIDES AND ACETYLENE COMMERCIALLY CONSIDERED.

BY T. L. WILLSON AND J. J. SUCKERT, PH.D.

DR. SUCKERT:—MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:

Before entering upon the subject matter of this paper, namely, the commercial consideration of the carbides and acetylene, we believe that a brief history of these compounds, their methods of formation and their chemical and physical properties, will be of interest to you. That carbon will combine directly with various metals under the influence of heat, has long been known to chemists, but these compounds, generally known as "carbides," have been but

imperfectly studied, and, with the exception, perhaps, of the carbides of iron, are hardly known.

The only group of carbides which interests us this evening is that of the carbides of the alkali and alkaline-earth metals, such as the potassium, sodium, barium, strontium and calcium carbides; for the reason that these are the only carbides which, when brought into contact with water, will decompose it, forming generally the hydrated oxide of the metal and acetylene gas. Of these latter carbides, the combination of calcium with carbon has the greatest commercial possibilities on account of the low first cost of the raw materials which enter into this combination, namely, lime and coal, the abundant deposits of same in all quarters of the globe, and the commercial value represented by the by-product, hydrate of lime, which is obtained in large quantities by the decomposition of the calcium carbide with water.

The history of the discovery and methods of production of this group of carbides may briefly be stated, as follows:

The first authentic reference to this subject was the discovery, by Sir Humphrey Davy, that carbon and potassium, when heated to a temperature sufficiently high to vaporize the potassium, formed a compound which, after cooling, would effervesce with water.

Berzelius, in 1836, determined that the black substance formed in small quantities as a by-product in producing potassium from potassic carbonate and carbon, was carbide of potassium.

Woehler, in 1862, prepared calcium carbide by fusing an alloy of zinc and calcium with carbon, and ascertained that it decomposed by contact with water forming calcic hydrate and acetylene.

Berthelot, in 1866, described sodium carbide or acetylene sodium. He produced it by the following method: Metallic sodium, when slightly heated in acetylene gas, puffs up and absorbs acetylene with the formation of the compound C_2HNa. At a dull red heat sodium destroys acetylene, forming a black carbonaceous mass, C_2Na_2. The reaction is expressed by the following formula: $(C_2H_2 + Na_2 =$

$C_2Na_2 + H_2$). This compound, C_2Na_2, in contact with water, regenerates acetylene.

From 1866 until 1888, a period of twenty-two years, nothing further has been recorded of scientific work done in this direction; as a matter of fact, the compounds so produced were not only very impure, but their cost of production also was so great as to render their commercial use prohibitory; they were considered as curiosities and looked upon by scientists as such. In 1888, Mr. T. L. Willson began a series of experiments relating especially to the reduction of refractory metallic oxides by carbon, in an electrical furnace. By this method the reductions were to be accomplished by the heat effect of the current alone, and not by electrolytic action.

The results of these experiments, which were numerous, and which extended over a period of years, developed some very interesting data as to the action of intense heat on refractory bodies generally, and especially as to the formation of carbides in large quantities. Mr. Willson found that lime, baryta, strontia and even alumina, when subjected to the intense heat of his electric furnace, were liquefied and formed a molten mass, which could be brought to ebullition. An addition of carbon thereto caused a decomposition of the oxide, carbon monoxide being formed, while the fused metal united instantly with the excess of carbon, previously introduced, to form a carbide. Further experiments developed the fact that when a mixture of powdered lime and coke dust was introduced into the furnace, the mixture would melt down to a thick syrupy mass of practically pure carbide of calcium, and that this, when removed from the furnace and brought in contact with water, evolved acetylene gas in large quantities. The carbides of barium, strontium and aluminum also were prepared in the same manner, and the specimens now before you are the results of these earlier experiments.

We will now introduce a small quantity of each of these carbides into different vessels containing water at ordinary temperature. The carbides of barium, strontium and calcium decompose water readily, forming the respective

hydrates of their metallic oxides and acetylene gas, which we now ignite as it is being evolved in each vessel; the resulting gas, as you observe, burns with a luminous sooty flame (see *Fig. 1*). As the carbide of aluminum does not react with water at ordinary temperatures, no gas is evolved from the fourth vessel.

This substantially completes the history of the alkali and alkaline-earth metal carbides up to the date of Mr. Willson's discovery.

The physical and chemical properties of pure calcium carbide, as first prepared in the Willson furnace, and which we now hand you for inspection, is a dark-brown, dense substance, having a crystalline metallic fracture of blue or brown appearance, and a specific gravity of 2·262; it evolves a peculiar odor when exposed to the atmosphere, due to the action of atmospheric moisture. In a dry atmosphere it is odorless. When exposed to the air in lumps, it becomes coated with a layer of hydrate of lime, which, to a great extent, protects the rest of the substance from further deterioration by atmospheric moisture. It is not inflammable, and can be exposed to the temperature of the ordinary blast furnace without melting. When exposed to the flame of a Bunsen blast-lamp it can be heated to a white heat, the exterior only being converted into lime. When brought into contact with water, or its vapor, at ordinary temperatures, it is rapidly decomposed, one pound generating, when pure, 5·892 cubic feet of acetylene gas at a temperature of 64° F. It also decomposes with snow at a temperature of — 24° F. It is not acted upon by the vapor of water at high temperatures. It abstracts moisture readily from alcohol, also from liquefied ammonia gas, rendering the latter anhydrous. If small pieces are treated with common sulphuric acid, a violent reaction ensues. Acetylene is generated with considerable increase in temperature. If, however, large pieces are plunged into common sulphuric acid, the reaction is feeble.

An exhaustive series of experiments, made by Dr. H. Schweitzer, of New York, have shown that when treated at a red heat with dry muriatic acid gas, the carbide is decomposed with the formation of free carbon and small quanti-

ties of a yellow substance easily soluble in ether. When treated with steam at different temperatures, (up to 428° F.), and different pressures (up to 35 atm.), the material was decomposed with the formation of but small quantities of the same yellow substance, and not in sufficient quantity for further examination.

Benzol, nitro-benzol, phenol, aniline, toluidine, and other organic compounds, gave no reaction when treated with carbide of calcium alone, and in the presence of water, at varying pressures and temperatures. It would appear from the foregoing to be a very inert body in its action on other compounds, and in view of this fact, the ease with which it decomposes water at ordinary temperatures is remarkable.

When treated with water in a closed vessel properly cooled, acetylene gas continues to be evolved from the material at pressures exceeding 75 atm. Calcium carbide has the chemical formula CaC_2, and contains in 100 parts 62·5 parts of calcium and 37·5 parts of carbon.

The gaseous product of the decomposition of the alkali and alkaline earth metal carbides with water, namely, acetylene, is an unsaturated hydrocarbon of the series C_nH_{2n-2}, having the chemical formula C_2H_2, and containing, therefore, in 100 parts, 92·3 parts of carbon and 7·7 parts of hydrogen.

It was first recognized, and its chemical constitution determined, by Berthelot, in 1849. It has heretofore been formed in small quantities by passing ethylene, or the vapors of alcohol, wood alcohol, ether, and other organic compounds, through a red-hot tube. It is present in coal gas to the extent of 0·06 per cent., and water gas contains almost 1·0 per cent. It has also been formed by passing hydrogen gas between carbon points brought to incandescence by the electric current, which is the first recorded synthesis of an organic compound directly from its elements. It can also be produced by the incomplete combustion of the vapors of ether, amylene, etc.; or of illuminating gas, in the interior of a Bunsen burner; by passing the vapor of chloroform over red-hot copper; or from chloroform and potassium

amalgam; or from chloroform and sodium; or by the electrolysis of fumaric and malic acids; by passing the vapor of ethylene chloride over red-hot soda lime; and finally, by allowing ethylene bromide to drop in a boiling concentrated solution of alcoholic potash, passing the impure acetylene into an ammoniacal cuprous chloride solution, washing the red precipitate with water, and, whilst still moist, boiling it with concentrated hydrochloric acid.

Acetylene is a colorless gas, having a penetrating pungent odor somewhat resembling garlic, which is of great importance in its application to household illumination, as it renders the slightest escape of gas in a room easily detectable. It has a specific gravity of 0·91, and burns with a luminous sooty flame. It is soluble in water in about the same proportions as carbon dioxide, that is, at 64° F. water will absorb its own volume of the gas. Absolute alcohol and glacial acetic acid dissolve about six times their volume. It is practically insoluble in saturated brine, 100 volumes absorbing but five volumes of the gas, whereas paraffine will absorb two and one-half times its volume. By heating acetylene to the softening point of glass, benzol (C_6H_6), styrolene (C_8H_8), naphthalene ($C_{10}H_8$), anthracene ($C_{14}H_{10}$), and reten ($C_{18}H_{18}$), are formed.

With an alkaline solution of permanganate of potash, acetylene is oxidized to oxalic acid, and with a dilute solution of chromic acid to acetic acid. By treating acetylene-copper with zinc and ammonia, ethylene is formed, and a mixture of acetylene and hydrogen, brought in contact with platinum black, forms ethane. By the electric spark, acetylene is resolved into carbon and hydrogen, at the same time a fluid and a solid poly-acetylene are formed; the latter resembles horn, and is insoluble in the ordinary solvents. A mixture of nitrogen and acetylene is converted by the induction spark into hydrocyanic acid.

It may be heated to a temperature of 370° F., and under a pressure of 43 atmospheres, without decomposition.

The gas can readily be condensed to a liquid, as is evidenced by the following table, the pressures being considerably less than those required for carbon dioxide.

Acetylene.		Carbon Dioxide.	
Fahr.	*Atmospheres.*	*Fahr.*	*Atmospheres.*
—116·°	1·0	—112·°	1·0
— 28·6°	9·0	— 29·2°	12·7
— 9·4°	11·01	— 4°	19·93
+ 14°	17·06	+ 14°	26·76
32°	21·53	32°	35·40
41·45°	25·48	41°	40·47
56·3°	32·77	59°	52·17
67·27°	39·76	68°	58·84

The critical point of the gas has been placed by Ansdell at 98·69° F. He also determined the specific gravity of the liquefied gas at various temperatures, placing the density at about one-half that of carbon dioxide; but his results do not agree with those obtained by us in the production and storage of large quantities of the liquefied gas. For instance, the small tank to which this connecting pipe and burner are attached (*Fig. 2*) should contain, according to Ansdell, when filled at 69·08° F., about 2·15 pounds of liquefied acetylene; as a matter of fact, however, we can fill into this tank somewhat more than two and three-quarter pounds of the liquefied gas. We are now engaged in preparing a new table of pressures and specific gravities of the liquefied gas, and will be pleased to communicate the results to you at a later date. One pound of the liquid, when evaporated at 64° F., will produce fourteen and one-half cubic feet of gas at atmospheric pressure; or a volume 400 times larger than that of the liquid.

The odor of the gas has already been made apparent to you whilst the experiment showing the decomposition of the various carbides with water was being carried on. We will now show you the liquefied gas contained in this glass tube surrounded by a metal casing (*Fig. 3*). As you will observe, the liquefied gas forms a colorless, mobile, highly refractive liquid, which, when the pressure is slightly relieved, commences to boil and evolves a gas which, ignited as it issues from this gas tip, burns with an intensely white flame. If the liquefied gas be suddenly relieved of its pressure, or allowed to escape in its liquefied state to the atmosphere, a portion evaporates rapidly, thereby abstracting from the remaining portion sufficient heat to solidify it. This tank,

which is now shown you (*Fig. 4*), contains liquefied acetylene, which has been cooled to a temperature of —28° F., in order to prevent the escape of too large a volume of gas during the process of its solidification. Attached to this valve, inside of the tank, is a tube which reaches within half an inch of the tank bottom, and is open at its lower end. We now attach to the valve a flannel bag to receive the solidified gas. Upon opening the valve the liquefied gas escapes, the solidified portion remaining in the bag, while the gas formed escapes through the pores of the bag. This bag will hold about three-quarters of a pound of the solidified gas, and this is about the quantity which is now being emptied on the plate. A portion of this solidified gas will now be passed to you for inspection; another portion is packed into this wooden tube, a thermometer is inserted

FIG 6.

(*Fig. 5*), and, as you will observe, the temperature falls to — 118° F. Another portion is placed on one pound of mercury contained in this saucer (*Fig. 6*); the intense cold of the solidified gas almost immediately solidifies the liquid metal. A portion of the solidified gas or "acetylene snow" is now dropped into this vessel (*Fig. 7*), containing water. Being lighter than water, it floats upon its surface, and when touched with a light the gas surrounding each particle of the solidified gas burns with a sooty flame, and continues to burn until all the solidified gas has disappeared. I will now ignite the gas evolving from the acetylene snow contained in this dish, and you have the interesting exhibit of a solidified gas at — 118° F., giving off gas which can be ignited, and which, although evolved at this low temperature, possesses the same illuminating power as at higher temperatures.

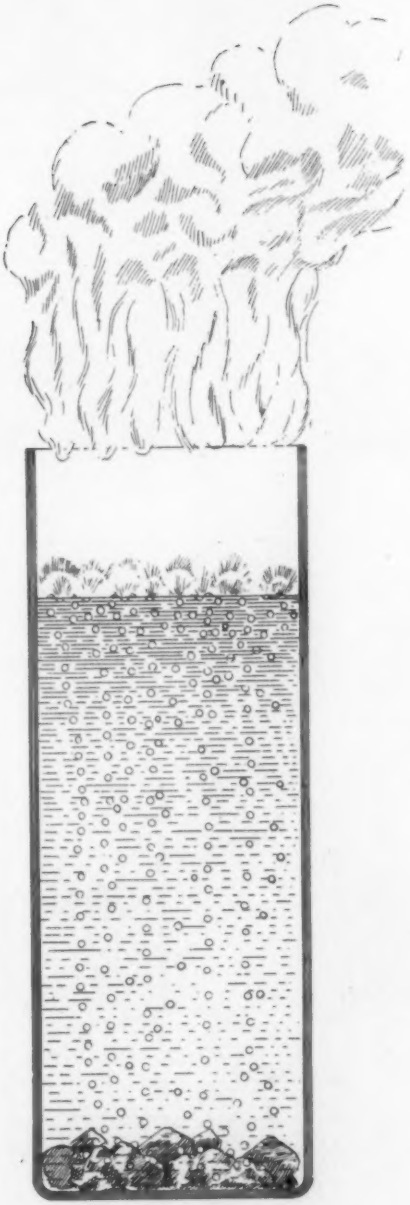

FIG. 1.

FIG. 2.

FIG. 3.

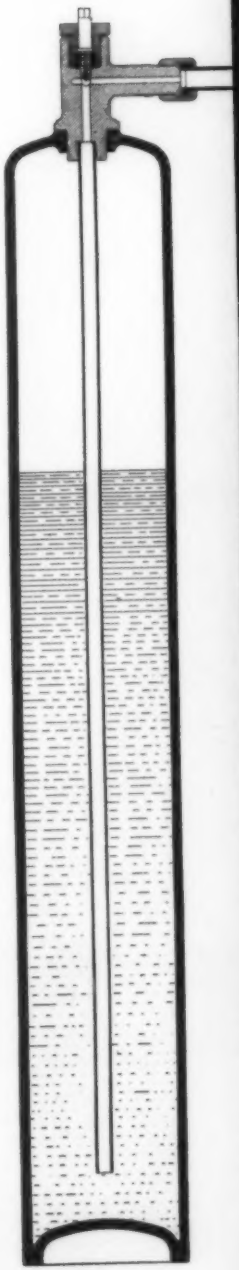

FIG. 4.

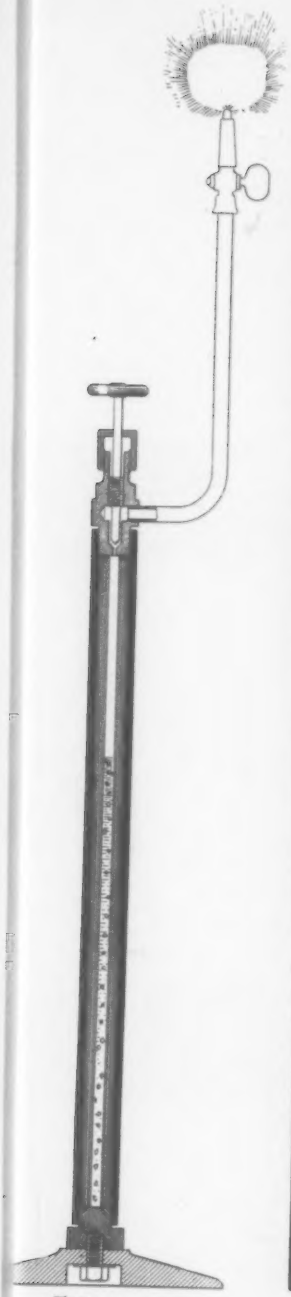

FIG. 3.

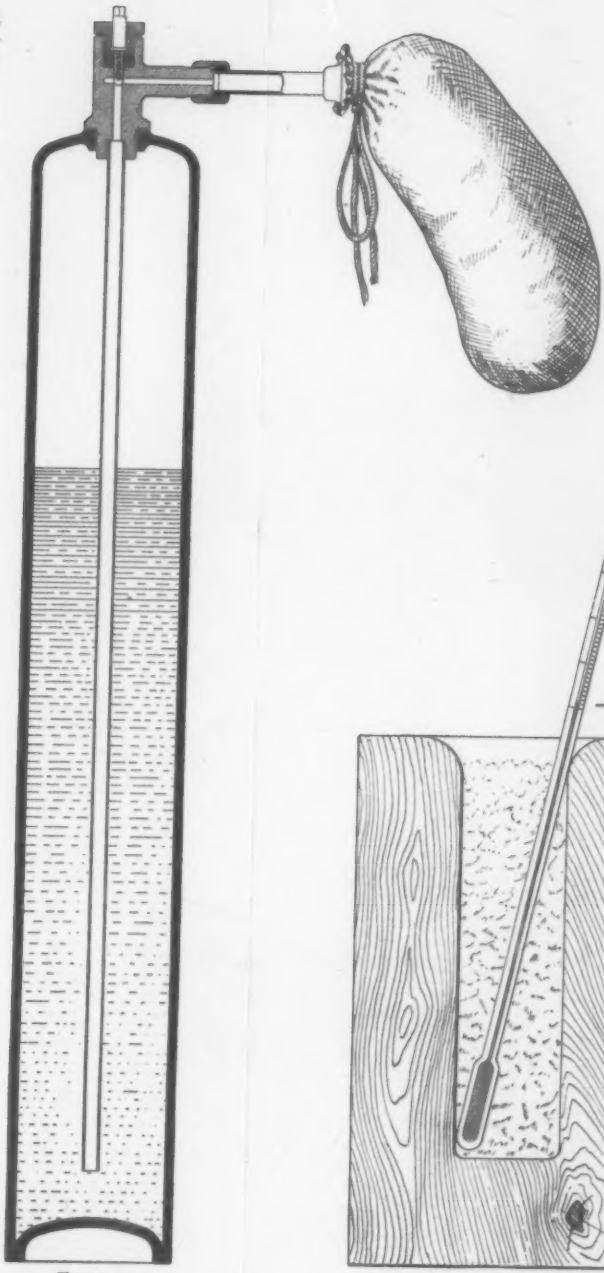

FIG. 4.

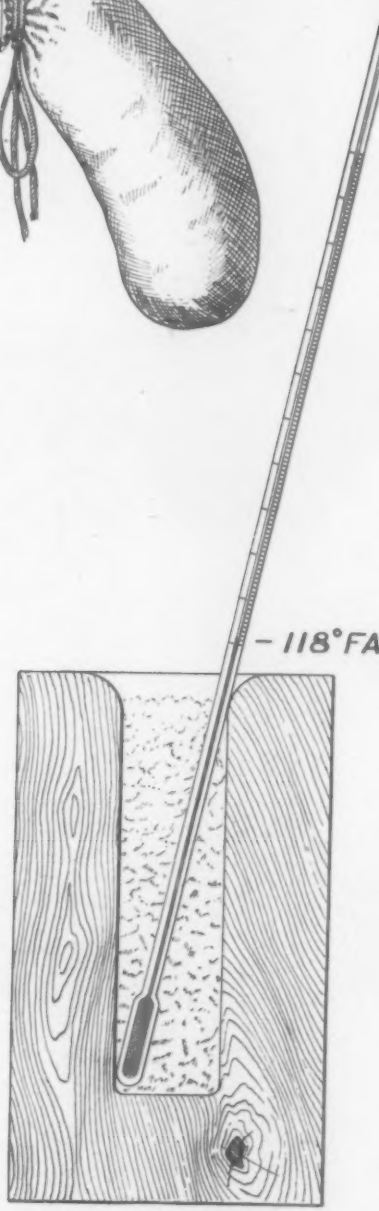

FIG. 5.

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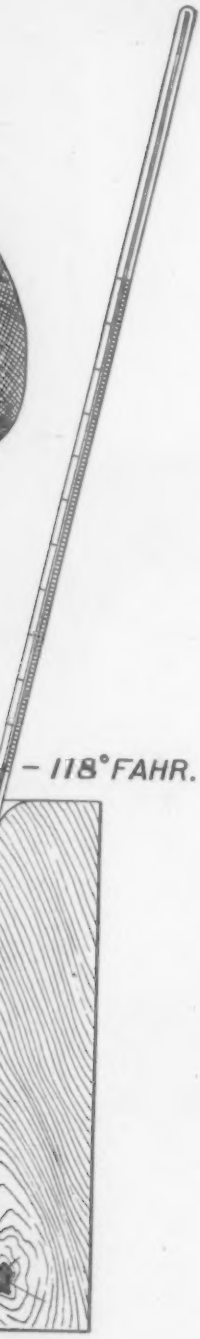

You have now seen acetylene in its three physical conditions, namely, as a gas, a liquid and a solid; and the mere fact that it readily assumes the gaseous and liquid condition is of vital importance to its commercial application.

COMMERCIAL APPLICATION.

Having described the physical and chemical properties of calcium carbide and the product of its decomposition with water—acetylene—we will now consider the commercial possibilities of these compounds.

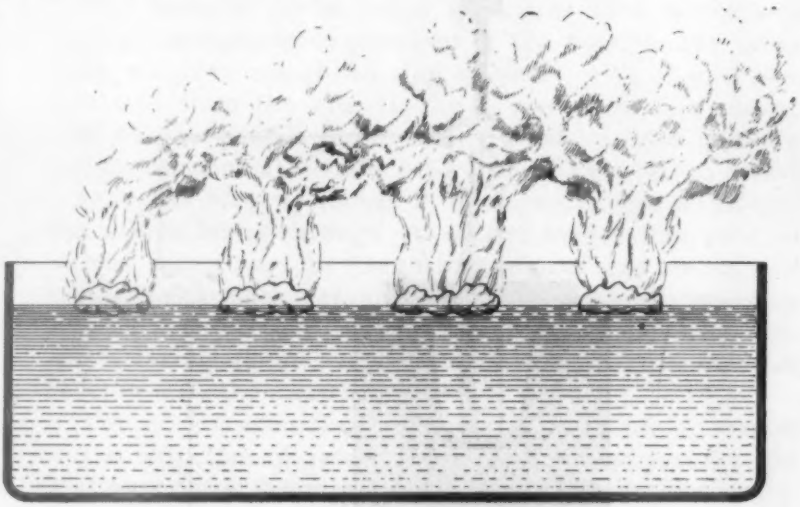

FIG. 7.

Carbide of calcium, as we have already shown, is a rich source of acetylene, but beyond this we cannot at present definitely designate additional commercial applications of this material.

Extended experiments are now being conducted to determine its commercial value in the production of cyanides and various nitrogenous compounds, in the manufacture of iron, steel and other metals, and their alloys, and in its application to the synthetical formation of various organic compounds.

The results thus far obtained, however, although encour-

aging, do not as yet justify us in accepting them as commercially applicable.

As the commercial value of any material largely depends upon its cost of production, its purity, and the value of the products and by-products obtained therefrom, our first consideration will be the method of manufacturing the carbide of calcium and the cost of the finished product.

The carbide of calcium originally prepared by Mr. Willson during his first experiments was produced at a cost

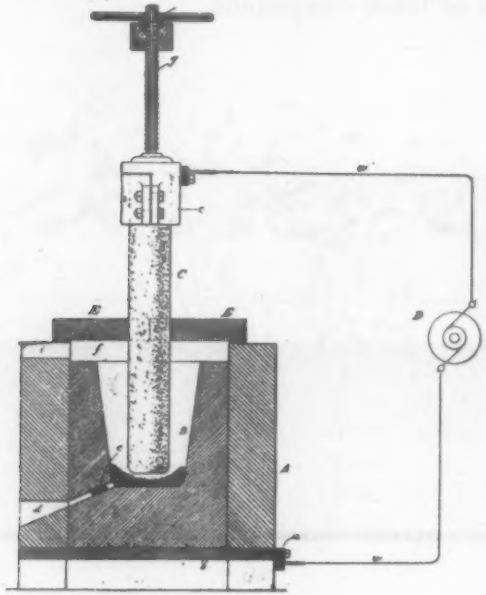

FIG. 8.

largely in excess of that for which it can be manufactured to-day, but a description of these original experiments will, without doubt, be of interest to you.

The first experiments were made with a dynamo generating a current of 150 ampères at from 60 to 70 volts. The furnace consisted of a plate of carbon 12 inches square and 1 inch in thickness, along one edge of which an iron rod was bolted and projected beyond the mason work, and to which one terminal from the dynamo was connected. This carbon plate was embedded in brickwork,

having only a small central portion exposed, upon which the graphite crucible rested. From one terminal of the dynamo, the current was conducted through the iron rod, carbon plate, graphite crucible, the material to be acted upon, and the carbon pencil, to the other terminal. To start the furnace, the pencil was placed in contact with the bottom of the crucible and the dynamo was started up slowly. As the electromotive force increased, the pencil was withdrawn from the bottom of the crucible and the "arc" established.

The material to be acted upon was then introduced through an opening in the cover of the crucible, the cover being either of non-conducting material, or, if of graphite, insulated from the crucible by a non-conducting luting. One of the pencils from the original lot used in these earlier experiments is now before you. This carbon pencil is 12 inches long, 1¼ inches in diameter, copper-plated and has a hole bored through its entire length, the tube so formed being used for the introduction of gaseous agents. With this furnace various metallic compounds, intermingled with pulverized carbon and also surrounded by gaseous reducing agents, were subjected to the intense heat developed by the electric arc.

The success attending the operation of this first furnace, in the reduction of refractory metallic oxides, justified the continuation of the experiments upon a larger scale, and to this end the Willson Aluminum Company was organized and a plant erected at Spray, N. C. This plant was supplied with a dynamo, operated by water-power, and generating a current of 2,000 ampères at 35 volts. The furnace was constructed as here shown (*Fig. 8*), namely:

A designates the outer masonry shed or bench of the furnace; *B*, the carbon or graphite crucible or hearth; *C*, the carbon bar or pencil constituting the movable electrode, and *D*, the dynamo for generating the current. From the terminal brushes of this dynamo, one wire, *w*, leads to and communicates with the crucible *B*, while the other wire, *w'*, leads to and communicates with the carbon pencil *C*. The connections are usually made in the manner shown,

the wire *w* being connected through a fastening-bar *a*, to an iron plate *b*, underlying the crucible *B*, and the wire *w'* being connected to a metal socket *c*, embracing the upper end of the carbon pencil *C*. The bench *A* is generally made of firebrick, which is a non-conductor of electricity, and the furnace is covered with a plate or, preferably, two plates, *EE*, of carbon, having a central hole, through which the carbon pencil *C* projects down into the crucible.

For tapping out the resulting product, a tap-hole *d* is formed which, in operation, is closed by a plug *e*, of clay or other suitable refractory material. The carbon plates *EE* rest on the top of the firebrick walls *A*, which project above the top of the crucible, forming an intervening space *f* for the furnace, between *B* and *E*. For the vertical adjustment of the carbon pencil a screw-threaded shaft *g* is provided, which may be moved up and down by the engagement therewith of a suitably-mounted rotative nut *h*.

The first carbide of calcium produced in this furnace, in accordance with memoranda taken at the time by Mr. Willson, was manufactured as follows: A mixture of lime and tar was boiled in a caldron, in the proportion of 60 pounds of lime to 11 gallons of coal-tar, and the heating was continued until the mixture was perfectly dry. It was then introduced into the furnace and subjected to the heat of the electric arc for a period of two hours, gradually feeding the mixture of lime and tar to the furnace as fusion took place. The product obtained consisted of a purplish-yellow mass, which, in contact with water, evolved acetylene gas. A sample of the calcium carbide produced upon this occasion is now before you, and represents the first calcium carbide produced in an electrical furnace.

The experiment was repeated with a mixture of 15 pounds of tar in fused lime and alumina, the time required for the operation being one and one-half hours.

The product obtained was a black, crystalline mass, consisting of a double carbide of calcium and aluminum. A sample of this double carbide is also submitted for your inspection.

Another run, made with a mixture of 10 pounds of lime and 10 pounds of finely-divided carbon, operating one hour,

resulted in the production of a dark, crystalline mass, showing at its fracture black and blue crystals. A small metallic ingot was found in this mass, and a similar ingot of this white metal is now before you.

A fourth test, made with 17½ pounds of lime and 17½ pounds of carbon, resulted in obtaining 11 pounds of almost pure calcium carbide.*

The tests described represent but a few of the numerous experiments conducted by Mr. Willson in his efforts to successfully and economically produce calcium carbide on a large scale. Recent results in the application of the alternating current to its manufacture prove conclusively that calcium carbide, of a remarkable purity, can be commercially produced. The product now being manufactured, in quantities exceeding one ton *per diem*, will readily evolve in contact with water 5¾ cubic feet of acetylene gas per pound of the carbide used, a result closely approaching to that which is theoretically possible, namely, $5\frac{89}{100}$ cubic feet per pound of carbide.

The theoretical proportions of lime and carbon required for the production of 100 pounds of calcium carbide are, 87½ pounds of lime and 56¼ pounds of carbon. Of the latter 37½ pounds combine directly with the metal calcium; and 18¾ pounds combine with the oxygen of the lime, and escape from the furnace as carbon monoxide, in accordance with the following formulæ:

$$\begin{aligned} CaO + C_2 &= CaC_2 + CO \\ 87\tfrac{1}{2} + 56\tfrac{1}{4} &= 100 + 43\tfrac{3}{4}\ \text{(lbs.)} \\ CaC_2 &= Ca + C \\ 100 &= 62\tfrac{1}{2} + 37\tfrac{1}{2}\ \text{(lbs.)} \\ CO &= C + O \\ 43\tfrac{3}{4} &= 18\tfrac{3}{4} + 25\ \text{(lbs.)} \end{aligned}$$

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* A sample of the carbide obtained during this last test was sent by Mr. Willson to Lord Kelvin, of the Glasgow University, and, in return, the following reply was received:

"THE UNIVERSITY, GLASGOW, October 3, 1892.

"DEAR SIR:—I have seen and tried the calcium carbide, only, however, so far as throwing it into water and setting fire to the gas which comes off. It seems to me a most interesting substance and I thank you very much for sending it to me. Yours, very truly,

"KELVIN.

"THOMAS L. WILLSON, ESQ."

A further element of cost in its manufacture is the production of heat in the furnace by means of the electric arc. Extended experiments in this direction have shown that one electrical horse-power will readily produce twenty pounds of calcium carbide each twenty-four hours, and the present indications justify the assumption that with automatically-fed furnaces, properly insulated to retain the heat, and by utilizing the waste heat to increase the temperature of the material acted upon, the production of calcium carbide can be increased on a large scale to thirty pounds per electrical horse-power each twenty-four hours.

By using limestone and coal dust, the latter being practically a waste product (not at present utilized), it is believed that calcium carbide can eventually be produced at a cost of less than $5 per ton. Where bituminous coal is employed, the value of the by-products obtained by its conversion into coke will largely reduce the cost of manufacture.

The hydrate of lime obtained from the decomposition of the carbide with water can be used again in the manufacture of the carbide, or it can be employed in the manufacture of ready-mixed mortar, which is already quite an industry in this city.*

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* The following details of the cost of producing 150 tons of calcium carbide *per diem*, as a by-product in the manufacture of 100,000 fire- and pressed-brick *per diem*, will, no doubt, interest you.

The figures were compiled by a manufacturer who was desirous of commercially utilizing the close proximity of large deposits of coal, limestone and clay. They show an annual profit of $535,640, with a selling price of $7 per ton for carbide.

JANUARY 19, 1895.

PRODUCT OF 1,400 TONS OF COAL, 450 TONS OF CLAY AND 270 TONS OF LIMESTONE.

150 tons of calcium carbide, at $7	$1,050 00
10 tons of sulphate of ammonia, at $70	700 00
40 tons of coal tar, at $7	280 00
910 tons of coke, at 90 cents	819 00
50,000 fire brick at works at $15	750 00
50,000 dry pressed front brick, at $15	750 00
	$4.349 00

5,445,000 FEET OF RICH ILLUMINATING GAS.

3,240,000 feet of this will produce 12,000 horse-power for 24 hours, allowing 1¼ pounds coal per horse-power, and 9 cubic feet of gas as the equivalent

Arrangements are now being made by the Electro-Gas Company, of New York City, with the Niagara Falls Power Company, to apply 1,000 electrical horse-power to the manufacture of calcium carbide, which is shortly to be increased to 5,000 horse-power, and, eventually, we will, without a doubt, see the entire available power the company now possesses converted into electrical energy for the manufacture of this product. The effect of such a production would be far-reaching, and the economies resulting therefrom, if stated to-night, appear exaggerated and visionary. Assuming that but 20 pounds of the carbide are produced per indicated horse-power each 24 hours, then the amount manufactured during 300 working days would be 3 tons per horse-power per year; and, applying 100,000 horse-power to its production, the annual output of such an establishment would be 300,000 tons. From this amount of material 3,300,000,000 cubic feet of acetylene gas should be produced, and as its illuminating power, compared with ordinary illuminating gas of 25 candle-power, is as ten to one, it would

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of 1 pound of coal. 1,485,000 cubic feet of gas will burn 270 tons of limestone, producing 150 tons of lime, allowing 1,100 pounds of coal per ton of lime, and 9 cubic feet of gas as the equivalent of 1 pound of coal. 720,000 cubic feet of gas will burn 100,000 bricks, allowing 800 pounds of coal per 1,000 bricks.

Expenses :

Mining 1,400 tons of coal, at 55 cents		$770 00
Mining 450 tons of clay, at 35 cents		157 50
Mining 270 tons of limestone, at 25 cents		67 50
Labor on 1,000 tons of coke, at 20 cents		200 00
Freight on 210 tons of limestone, at 50 cents		135 00
Labor in grinding 150 tons of lime, at 25 cents		37 50
Labor in making 100,000 brick, at $2 per M		200 00
Labor in smelting calcium carbide		150 00
		$1,717 50
Twenty-five per cent. on $1,717.50 for general expenses		429 37
		$2,146 86
Interest on plant per day		83 33
		$2,230 20
Income	$4,349 00	
Expenses	2,230 20	
Net income per day	$2,118 80	
Net income per year (300 days)	$635,640 00	

represent fully 33,000,000,000 cubic feet of this gas—an amount which would probably equal the annual output of the entire gas industry of the United States.

As this is but one of the many applications of the product obtained by the decomposition of the carbide with water, the manufacture of the carbide itself must, of necessity, become a large industry.

As we have previously informed you, pure calcium carbide contains, in 100 parts, 37·5 parts of carbon and 62·5 parts of calcium, and when brought in contact with water, acetylene is generated to the extent of 5·89 cubic feet of the gas to each pound of carbide used; or if compared by weight, 100 pounds of calcium carbide and 56·25 pounds of water evolve 40·63 pounds of acetylene gas, and form 115·62 pounds of calcic hydrate, in accordance with the following formula:

$$CaC_2 + 2H_2O = CaOH_2O + C_2H_2$$
$$100 + 56{\cdot}25 = 115{\cdot}62 + 40{\cdot}625 \text{ (pounds.)}$$

The acetylene gas so generated contains, in 100 parts, 92·3 parts of carbon and 7·7 parts of hydrogen, or in the 40·625 pounds generated from 100 pounds of carbide, we have $37\frac{1}{2}$ pounds of carbon and $3\frac{1}{8}$ pounds of hydrogen. The entire carbon contained in the calcium carbide has, therefore, combined with the hydrogen of the decomposed water to form a new compound of a gaseous nature and extremely rich in carbon.

In its commercial application acetylene can be produced either directly from the calcium carbide by decomposition with water, or it may be evolved from the liquefied gas contained in suitable receivers.

When manufactured directly from the carbide, two methods can be employed; in one, small quantities of water are allowed to flow upon the carbide and the resulting gas is conducted to an ordinary gasometer, from which it can be drawn for use; this method is more or less intermittent. The other method dispenses with a gasometer and permits the continuous generation of either large or small quantities of the gas, and this is accomplished by partially sub-

merging in water a vessel, open at the bottom and containing carbide suspended on a screen in the upper part of the vessel, the generated gas being withdrawn from above the carbide. As long as gas is being used the water remains more or less in contact with the carbide; as soon, however, as the withdrawal of gas diminishes or entirely ceases, the pressure of the generated gas forces the water from the carbide into the lower chamber of the vessel, thereby preventing a further generation of the gas. The apparatus is automatic and extremely regular in its operation.

In the employment of either of the above methods, the only by-product obtained is slaked lime, the amount of gas produced being the same, namely, 5½ cubic feet for each pound of calcium carbide used.

The liquefied gas is manufactured commercially by decomposing the carbide of calcium with water in a closed vessel, and conducting the gas generated under pressure to a condenser, where it liquefies and is then drawn off in tanks ready for distribution.* The liquefied gas, exhibited this evening, has been produced in this manner.

Before entering upon the use of acetylene as an illuminant, we desire to call your attention to the fact that its rapid and extraordinary development in this direction is largely due to the individual efforts of Mr. E. N. Dickerson, of New York City, who, endowed with a special knowledge of the subject, has labored unceasingly to bring about the successful result which you will see this evening.

As an illuminant, acetylene surpasses in lighting power and economy all other illuminants known; when burned at the rate of five cubic feet per hour, it produces a light equal to 250 candles, whereas the best illuminating gas made from coal, or water gas, rarely exceeds twenty-two candles for each five cubic feet burned per hour. Your Philadelphia city gas is rated at from nineteen to twenty candles. Acetylene gas will, therefore, produce twelve and one-half times more light if the same quantity be consumed, or, 1,000 cubic feet of acetylene gas will give you the equivalent in

*A full description of this process and of the apparatus required therefor, is contained in U. S. Patent, No. 535,944, March 19, 1895.

lighting power of 12,500 cubic feet of your city gas; it has, therefore, twelve and one-half times the value. To illustrate more fully the difference, we will first pass your city gas to the tube attached to this stand, and ignite the gas as it issues from the burners; we then conduct acetylene gas to a similar row of burners, and light these; the contrast, as you will perceive, is almost marvelous.

The acetylene consumed in these burners has been generated, in the apparatus before you, in the following manner: Upon the carbide contained in this closed jar (*Fig. 9*), water is poured in small quantities through the glass funnel communicating with the interior of the jar. The acetylene gas generated passes through this tube to the inside of the gasometer, thereby lifting the holder to the position which it now occupies, and the gas can then be conducted from the holder to the burners by means of this rubber tube. As the gas is being consumed and the holder lowers, the supply is rapidly renewed by pouring an additional amount of water through the funnel upon the carbide contained in the closed jar. We will also light the gas produced from liquefied acetylene contained in this small tank (*Fig. 10*), and, as you observe, it burns with the same brilliancy and lighting power as the gas produced directly from the carbide.

The liquefied gas contained in the small tank weighs just two pounds, and is capable of generating twenty-nine cubic feet of acetylene gas, which is at the rate of fourteen and one-half cubic feet per pound. The gas produced by the vaporization of the liquid at a pressure, as the gauge now indicates, of forty atmospheres, passes from the tank to a reducing valve upon which the tank stands, whereby its pressure is reduced to that of a two-inch water column, as indicated on this **U** water gauge, and it is under this pressure that we are supplying the gas to the burners attached to the arm above. Each of the burners supplied with acetylene gas will consume, at the pressure indicated, $1\frac{2}{10}$ cubic feet per hour, each, therefore, emits a light equal to sixty candle-power; the total candle-power of the six burners in use is, therefore, 360, and the amount of gas consumed each hour $7\frac{2}{10}$ cubic feet. To obtain this result with city gas

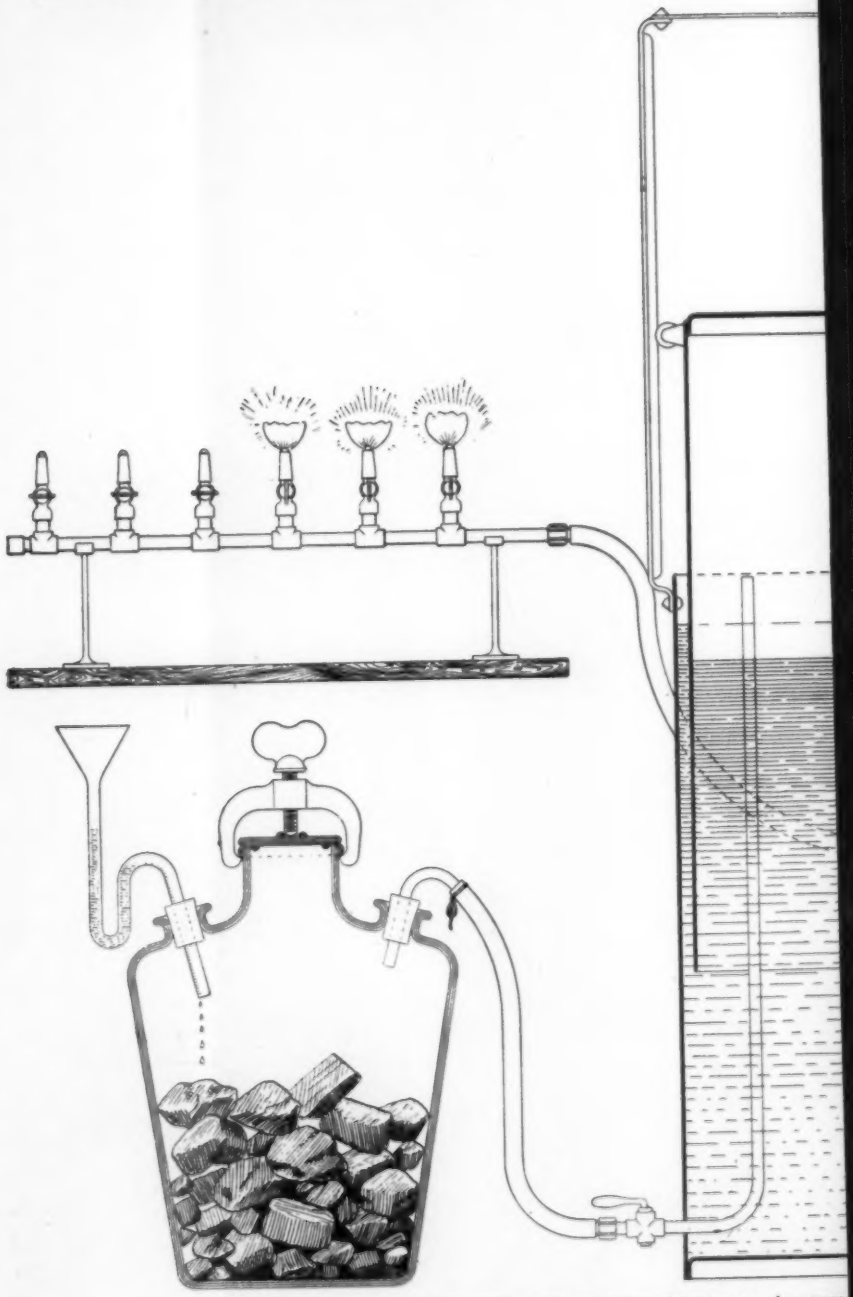
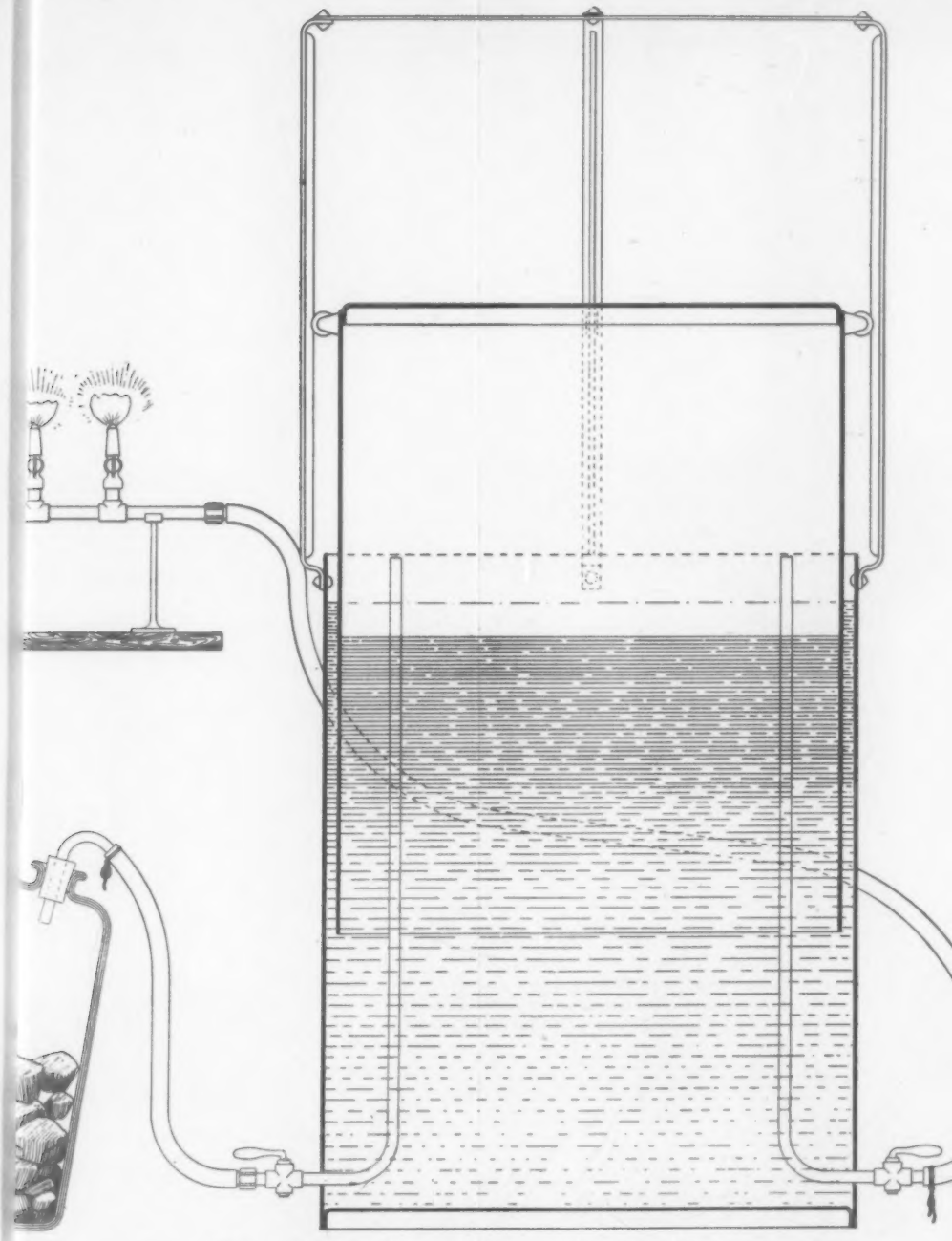


FIG. 9.—APPARATUS FOR THE MANUFACTURE OF ACETYL



PPARATUS FOR THE MANUFACTURE OF ACETYLENE FROM CALCIUM CARBIDE.

son and Suckert.)

would require the consumption of at least ninety cubic feet per hour.

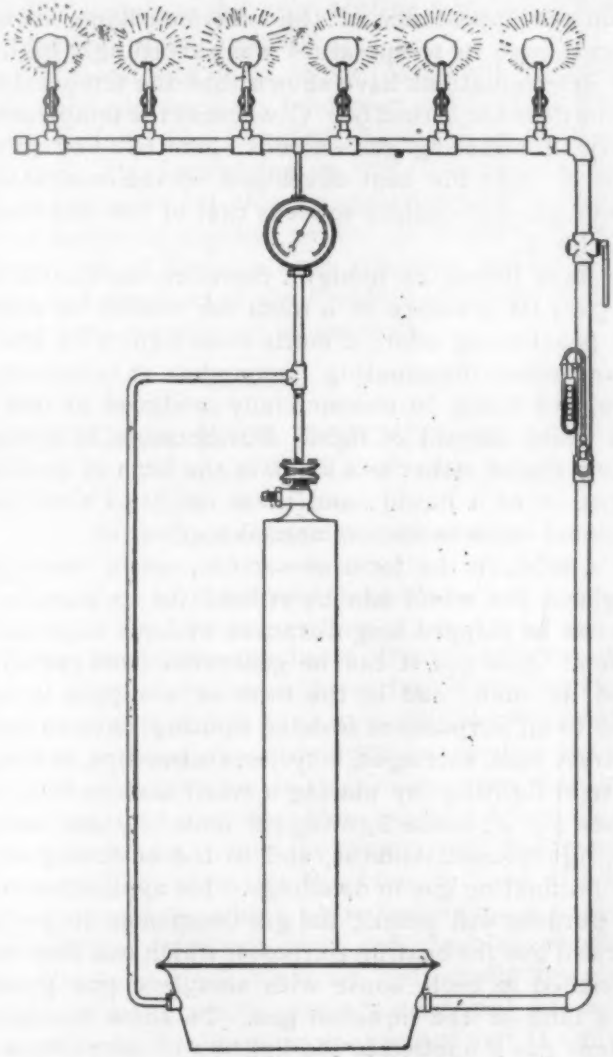


FIG. 10.

The amount of oxygen withdrawn from the atmosphere of this room by the acetylene for the same amount of light, is but one-sixth of that required for your city gas; the

products of combustion are, therefore, reduced in proportion and the air of the room is not vitiated to the same extent.

From the appearance of the acetylene flame it would seem as though its temperature was exceedingly high; but recent determinations have shown that the temperature of the flame does not exceed 900° C., whereas the temperature of ordinary illuminating gas exceeds 1,400° C. For an equal amount of light the heat developed by the combustion of acetylene gas but slightly exceeds that of the incandescent electric lamp.

We have before us to-night, therefore, an ideal illuminating gas; its presence in a room can readily be detected by its penetrating odor; it emits more light with less heat than any other illuminating compound; it consumes less oxygen, and it can be commercially produced at less cost, for an equal amount of light. Furthermore, it is capable of being stored either as a solid, in the form of carbide, or as a gas, or as a liquid; and these qualities alone are of exceptional value in its commercial application.

As a solid, in the form of carbide, waste water-power throughout the world can be utilized for its manufacture, and it can be shipped long distances without material deterioration. As a gas, it can be generated from carbide and applied as such; and in the form of a liquid, it can be applied to all purposes of isolated lighting, such as railroad and street cars, carriages, bicycles, steamships, sailing vessels, street lighting (by placing a small tank in each lamp-post (see *Fig. 2*), house lighting (in both city and country), buoys, lighthouses, lanterns, and to the enriching of ordinary illuminating gas in dwellings. Its application to this latter purpose will permit the gas companies to produce a low-priced gas for heating purposes, which can then readily be enriched in each house with acetylene gas generated from a tank of the liquefied gas. To show the value of acetylene gas if applied to the lighting of your city, we will make a comparison, which may surprise you. The amount of gas produced by your city works will approximate 4,000,000,000 cubic feet per year, of, say, twenty candle-power. By the use of acetylene gas, the amount of gas required

would be reduced in the proportion of 1 to 12·5; or, 4,000,000,000 cubic feet of city gas could be replaced by 320,000,000 cubic feet acetylene gas, representing a saving of 3,680,000,000 cubic feet of gas annually.

In addition to its value as an illuminant, acetylene gas can be used commercially for power and heating purposes; and in the form of a liquefied gas it will be invaluable for such use. Its application in this direction is, however, such an extensive one that we are compelled to make it the subject matter of another paper. In conclusion, we desire to thank you all for your kind attention, and especially the officers and members of the Franklin Institute, for the interest they have manifested in our work.

THE NATURAL SODA DEPOSITS OF THE UNITED STATES.*

BY DR. THOS. M. CHATARD.

[*Concluded from p. 283.*]

About two miles northeast from Ragtown one may notice a slight elevation on the surface of the desert, but the ascent is so gentle that one can hardly appreciate it. Suddenly, and without preparation, one comes upon the brink of a precipitous depression in the desert, more than 300 acres in area, the rim being more than 150 feet above the surface of the lake, which covers the greater part of the bottom of the cavity. The shores of this lake are lined with the vats of the soda-makers, whose white houses make a pretty contrast with the green salt grass and the blue waters of the lake. Flocks of small birds are continually hovering over the lake, and the whole presents a scene of life and color, the more beautiful because unexpected and in sudden contrast to the burning sand without, where beauty is represented by the horned toad and life by the tarantula.

* A lecture delivered before the Franklin Institute, February 23, 1894.

An eighth of a mile away, and separated by a narrow ridge, is another depression similar to the first, and called the Little Lake. While less attractive, it is quite as interesting; perhaps even more so.

Both of these depressions are evidently the craters of extinct volcanoes. The walls are composed of loose, sandy materials intermixed with pieces of rock, often two or three feet in diameter, and which are evidently volcanic ashes with larger masses of scoria. The deepest place in the lake is 312 feet below the highest part of the rim, and, as the surface of the water lies many feet below the bed of the neighboring Carson River, it is evident that these lakes, which have no apparent feeders and no outlets, are supplied by seepage from the river.

The water of the Big Lake is a strong solution of salts, mainly common salt, but with a large proportion of sulphate and of the two carbonates. You will remember that I have already told you that natural soda is composed of sodium monocarbonate and bicarbonate, with varying proportions of other salts, mainly chlorides and sulphates. Now I wish to impress upon you that, in nature, these two carbonates are always found together, and, furthermore, that if one exposes the solution of pure monocarbonate to the action of the air, the solution absorbs carbonic acid and a portion of the monocarbonate is converted into bicarbonate. The presence of the carbonate in this water must be accounted for by the decomposition of the volcanic ash through the action of air and moisture, as already described, the soluble salts thus formed being leached out of the mass by the river seepage, conveyed to the crater, and then concentrated by evaporation. The change of the monocarbonate into bicarbonate is continually going on, but appears to pause whenever the relation between the two salts reaches a certain limit, and the phenomenon is most important, as it gives us the only means of extracting the valuable carbonates from the accompanying useless salts.

For many years past the extraction of sodium carbonate from the waters of the Big Lake has been an established industry. The method is ingenious, and although, because

of natural disadvantages, the annual production is small, the work done here has yielded much valuable practical information which is now being utilized on a larger scale at Owens Lake in California. As this latter place must be described later, we will not linger at the Big Lake, but pass to its companion, where we shall see an operation which is singular of its kind.

The Little Lake, which gave its name to the smaller crater, has been completely altered in appearance. There are four large, irregular-shaped excavations, besides a shallow pool of fresh water from small springs which issue from the sides of the crater. Two of these excavations are situated upon the ledge, which is a natural deposit of crystal soda, of unknown but considerable extent and thickness. These lye pits are filled from the pool with water, which gradually becomes saturated with the soda dissolved from the ledge. The liquid from the lye pits is drawn off from time to time into the crystallizers, as the other excavations are called. By the end of the summer the crystallizers are filled with a saturated solution of soda, which, during the winter, crystallizes out as the ordinary crystal soda. When no more crystals appear to form, by which time the deposit is ten or twelve inches thick, the crop is gathered, and carefully stacked, preparatory to the drying process, which is the most delicate part of the work. Soda crystal contains sixty-three per cent. of water and parts with most of it with great ease and rapidity, so that if heated to 90° F., a temperature much below the ordinary summer heat of the region, it melts in its own water of crystallization and becomes a liquid. In drying the crop, great care must, therefore, be exercised, lest the material becomes liquid, and much of it thereby lost.

The crop is, therefore, kept in the stacks until the approach of warm weather, when it is broken up and spread in a layer two or three inches deep, on drying floors, which are covered with light sheds open at the sides. The material is turned over from time to time. When the drying is completed, the product is a thoroughly effloresced, white powder; the annual product is about 300 tons.

Returning to Wadsworth, we can then strike in a northwestwardly direction through the region known as the Black Rock Desert, which, in summer, is a succession of alkali flats containing much soda, and in winter, an almost impassable morass. This extends almost up to the border of Oregon, in the southern portion of which State lie Abert and Summer Lakes, which, though now inaccessible, must in time become valuable, since in their waters the proportion of sulphate, which is very deleterious to the quality of the soda, and must, therefore, be kept out as much as possible in the extraction process, is smaller than in any other large source of natural soda that is known.

Leaving the Central Pacific Railroad, at Reno, Nev., we can go southward by the Virginia and Trucker Railroad, and the Carson and Colorado to Hawthorne, Nev., where we can reach Mono Lake, near Bodie, Mono County, Cal.

This is a large lake, covering 85 square miles, with an average depth of 60 feet, and lies in a region of fine scenery; but, as to its future, I can only repeat what I have elsewhere said, "that this large body of water, of a composition so favorable to utilization, is for practical purposes inaccessible, and that the high altitude and consequent shortness of the evaporating season would, under any circumstances, render the success of any industry established there very doubtful."

Proceeding southward from Mono Lake, we pass over a highly volcanic country and reach Long Valley, in which the Owens River originates. This valley is full of alkali flats, morasses and pools, the alkali being, as before, derived from the decomposition of the volcanic rocks, a process which is now going on and can everywhere be observed. The drainage of the valley is by the Owens River, a stream which carries a considerable amount of alkali, all of which finally reaches Owens Lake, Inyo County, Cal.

This lake is the most important occurrence of natural soda in the world. Its area is even greater than Mono Lake, being over 100 square miles, with an average depth of not less than 17 feet. It is readily accessible, as the Carson and Colorado Railroad runs along the eastern shore, and can easily be reached by all of the great continental lines.

The lake lies between the Sierra Nevada on the west, and the Inyo Range on the east, and has no outlet, the lowest point of the rim of the valley being, as I am informed, about fifty feet higher than the present level of the lake. On the western side, several small brooks from the Sierra make their way into the lake, but the larger portion of the water supply comes from the Owens River, which empties into the lake at its northern end. This stream was, in February, 1892, about 59 feet wide, 5½ feet deep, and had a flow of about 3 miles an hour. These measurements represent a considerable amount of water, but represent probably not more than two-thirds of the daily supply; and one gets some idea of the aridity of the climate, and of the rapidity of evaporation, when one remembers that although the lake is naturally somewhat higher in the spring than in the autumn, the average depth suffers but little change. Hence, at present the evaporation from its surface seems to be about equal to the amount of water received from all sources. As the valley lies between two high ranges of mountains, and is open to the north and south, there is usually a good breeze through the greater part of the twenty-four hours, thus much increasing the evaporation, which may safely be taken as over five feet per annum.

The Sierras rise rapidly from the lake, and the peaks are very lofty. Mt. Whitney, which is in plain view, is the highest mountain in the United States. They are well timbered, and their vast, sombre masses form an agreeable contrast to the opposite glaring, light-colored Inyo Range, which is almost destitute of either wood or water.

Between the Inyo Range and the lake, the valley slopes gently from the foothills to the water edge, affording excellent locations for manufacturing purposes. The shore is covered in most places with a strong growth of salt grass, though there are extensive flats, which are bare.

In the lake itself are large quantities of a sort of "algous or fungoid plant, floating in globular masses of a whitish or yellowish green" (Loew). This collects upon the water in patches, and becomes black with the clouds of alkali flies or ephydra, which settle upon it. In addition to the larvæ

of these flies the water swarms with the little "alkali shrimp," or artemia. Both of these forms of animal life seem to be inseparable from alkali pools, being found in almost every one of them throughout the world.

The scenery of this valley is very attractive, and the soil, wherever irrigated, has proved itself to be very fertile. Very little snow falls in winter, and work can be done throughout the year. Even in summer, although the thermometer shows a high degree of heat, this is not oppressive, because of the dryness of the air, and sunstroke is, I believe, unknown. The highest temperature I have ever noted, the thermometer being in an exceptionally well-shaded place, was 109° F. Hot as this may seem, I spent the entire day at work in the sun with no protection and with no inconvenience, nor did any of the men working around me make any complaint. Indeed, a wilted collar is an impossibility in such a climate, as perspiration evaporates as fast as formed, and it is only necessary to drink a reasonable amount of water, and that not too cold, to have a far more comfortable time than is given to us by our Eastern summers. What is said of Owens Valley is true of the entire western side of the Great Basin, and whatever you may hear of the hardships that travellers may undergo, rest assured that those who are acquainted with the region find our Eastern climate much inferior.

At the village of Keeler, the terminus of the Carson and the Colorado Railroad, on the eastern side of the lake, are the works of the Inyo Development Company, which has been extracting soda from the lake waters since 1886, and is gradually developing a valuable industry. So far the company has confined its operations to supplying the wants of the borax makers along the line of the railroad, but can at any time speedily expand its operations to produce large amounts of high-grade soda ash.

The composition of the waters of Owens Lake is typical of all of the lakes which we have now hurriedly visited, and the method of extraction here employed is applicable to all of them in both its present stage of development and its future possibilities. We have, therefore, reached the point

where we can consider what this water is and how its valuable constituents can be utilized. I am not going to weary you with columns of analyses, or with technical details, for all these things have been published and can be read; but will try to give you a broad view of the whole subject, for in that way you will be able to form a much better idea of the greatness of the future.

I have told you that the waters of these lakes contain, as their principal constituents, sodium salts (mainly chloride, sulphate, carbonate and bicarbonate), together with some borax and some potassium salts. Of these salts only the carbonate and bicarbonate have any prospective value. These waters have all been carefully and repeatedly analyzed, and the area and depth of Abert, Mono and Owens Lakes fairly well determined. The amount of the two carbonates in each of these lakes can, therefore, be calculated, and the results are as follows:

Abert Lake has an area of 40 square miles and an average depth of 10 feet; Mono Lake, 85 square miles and depth of 60 feet; and Owens Lake, over 100 square miles, average depth 17 feet.

Taking these areas and depths, and knowing the amount of each salt in a given volume of the water, we obtain for the number of tons of carbonate and bicarbonate in these lakes the following surprising figures:

	Sod. Carb., Tons.		*Sod. Bicarb, Tons.*	
Abert Lake,	3,428,352	(3½ millions).	1,560,000	(1½ millions).
Mono Lake,	75,072,000	(75 "	17,936,000	(18 "
Owens Lake,	39,875,200	(40 "	8,431,000	(8½ "
Total,	118,375,552	(118 millions).	27,927,000	(28 millions).

Vast as this amount may seem, we must not forget that we are considering but three localities, leaving out the Ragtown Lakes, Summer Lake, the Black Rock Desert, Long Valley and many other places, which probably aggregate a far larger amount. It is, therefore, no exaggeration to say that within a belt of country fifty miles wide and extending from Abert Lake, in southern Oregon, to Owens Lake, in southeastern California, the amount of sodium car-

bonate, in the form of dry deposits, or of strong solutions, is more than sufficient to make 250,000,000 tons of soda ash.

Now, no one who knows that country, will doubt these figures; but for all that, some hard-headed man of business in this audience is probably talking to himself thus:

"I have no doubt of it. I am also well aware that unlimited quantities of a very superior quality of ice exists at the North Pole, but I am quite sure that ice will not be any cheaper in Philadelphia next summer for that reason. I have also been told that all sea water contains gold, but have never heard of any one getting rich from sea water unless he was a pirate or a hotel keeper."

Our friend is quite right. However lavish Nature may be, her gifts are wasted unless she so bestows them that they can be used by man. Most of these localities are at present inaccessible, and it may never be possible to make use of Mono Lake and of many of the smaller localities; but I feel that I am not exaggerating when I say that, at Owens Lake alone, there are space and facilities for works large enough to produce 250,000 tons of soda ash yearly, or the present annual consumption of the United States. Moreover, by a small addition to the present railroad facilities, this entire amount can be profitably made and distributed at present prices. Remembering also how much soda already exists in the lake, and that the latter is continually receiving additions through drainage, you will see that even this large production could only slowly reduce the supply.

It now remains to show you how this work can be done. The fundamental principles of a correct extraction process are these: The solubility of sodium bicarbonate is much less than that of either sulphate, chloride or the ordinary carbonate. At the ordinary temperature of 60° F., 100 parts of water dissolve 36 parts of sodium chloride, 16 parts of sodium carbonate, 13 parts of sulphate, and less than 9 parts of bicarbonate. With rise of temperature the solubility of sodium carbonate and of sulphate increases greatly, so that, at the summer temperature of 90° F., 100 parts of water can dissolve 46 parts of carbonate, or 50 parts of sulphate, but only 11 parts of bicarbonate. The solubility of bicarbonate

is also much diminished if chloride or sulphate is also present in the solution. If a solution containing equal parts of sodium chloride and bicarbonate is allowed to evaporate, it will be found that almost all of the bicarbonate will crystallize before the chloride begins to deposit, and the same is the case if sulphate is substituted for the chloride, though the separation is not so sharply defined.

Now, if sodium carbonate is also present in such a solution, the bicarbonate, in depositing, takes with it a certain definite proportion of carbonate, and forms with it a well-crystallized salt of definite composition. This double salt has long been known to mineralogists under the name of "urao," but its importance in the technology of natural soda has only lately been recognized. Upon the properties of this salt depends the entire process by which high-grade soda ash can be made from the impure natural soda. We will, however, call it "summer soda," the name given to it at the Big Lake at Ragtown, and at Owens Lake, where it is the product of the crystallizing vats.

When the solution of natural soda, such as the water of any of these lakes, is allowed to evaporate at any temperature below 150° F., a crop of crystals will be obtained. The crystals are colorless needles or prisms, and, if the evaporation is not pushed too far, will be practically free from sulphate or chloride. The composition is quite constant, and the salt may be considered as made up of 47 parts of sodium carbonate, 37 parts of bicarbonate, and 16 parts of water of crystallization. If a solution contains monocarbonate, sulphate and chloride, but no bicarbonate, it will be difficult to separate the carbonate from the other salts; but if bicarbonate is present, this will separate first, and, in depositing, every 37 parts will take with them 47 parts of carbonate. In this way we are able to extract from such a solution a very large proportion of its valuable constituents, the other salts remaining in the mother liquor.

When this "summer soda" is heated to a temperature not much above 300° F., it readily parts with its water and the excess of carbonic acid belonging to the bicarbonate, and the residue is a compact "soda ash" or sodium carbon-

ate. It is therefore apparent that, to make a good soda ash from natural soda, is a very simple matter. Of course, to produce the largest possible amount from a given quantity of raw material, and to do this in an economical manner, involves a great many other considerations and a thorough technical training, but such details are foreign to this evening's purpose.

I may, however, say here that the carbonic acid which is given off in the process of converting this summer soda into soda ash must be utilized as closely as practicable in any rational manufacturing method, and this can be done by absorbing it in the raw solution, thus increasing the proportion of bicarbonate and the consequent yield of summer soda. If the carbonation of the raw solution be pushed far enough, almost all of the carbonate can be converted into bicarbonate and thus be separated in one operation. This, indeed, will occasionally be found advisable in practice, but the greater part of the ash will always be made from summer soda obtained by spontaneous crystallization, for which the hot and arid climate of the region is especially favorable, and enables the soda-maker to do his work with the minimum expenditure of fuel. In such a region, fuel will always be an expensive item, and manual labor will be scarce and, consequently, costly. The use of labor-saving devices and machinery naturally suggests itself, but will be limited by the cost of the necessary motive power, although any extra expense for this will probably be covered by greater efficiency in work and greater uniformity of product. The forms of machinery and furnaces used in the other soda processes are not suitable for this industry, though the principles can be applied with substantial modifications in design. The furnace temperatures are low, and thus fuel is saved; but careful management is necessary, and the furnace must be continuous and nearly automatic. The utilization of the furnace gases and the economical handling, packing, shipping, transporting and marketing of the products, present many interesting problems which may have to be solved by novel devices and arrangements. In general, the distance to the ultimate market will be great, and every saving will be necessary.

In conclusion, I can only repeat what I have said upon another occasion: "It would seem that the time must soon come when these vast natural resources will attract the serious attention of capital and business enterprise. The path is open. The general chemical lines are already well known, and the engineering problems, while numerous, are neither very complex nor very difficult. With the steady development of the transportation facilities of the far West, it may reasonably be expected that those arid regions will soon become the seat of a new, great and prosperous industry.

RECENT ADVANCES IN ELECTRO-CHEMISTRY.*

By Joseph W. Richards, A.C., Ph.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Electro-chemistry is that division of chemical science which treats of the mutual relations of the electrical and chemical forces; it discusses the electrical effects of chemical action and the chemical effects of electrical action. This field has received a due share of attention in the century which has elapsed since it was opened to cultivation, but it is only within very recent years that its immense expansion, in both applied and theoretical aspects, has lifted it into the position of a distinct science.

To be qualified as an electro-chemist, the scientist must, first of all, be a chemist, knowing all that is implied by that term; and in addition to this, he must also be well informed in applied and theoretical electricity. But men thus qualified are few in number. Chemists generally have a smattering of electricity; electricians, as a class, know less about chemistry, so that the scientist who is

* A lecture delivered before the Franklin Institute, February 1, 1895.

master in both sciences may be termed a *rara avis*. Nearly all electro-chemical processes can be carried on only by the practical chemist, while the electrician plays a subordinate role.

The rapidly-growing importance of the applications of electro-chemistry has created a need for educated electro-chemists, with the above-described qualifications. The universities are looked to as able, if they will, to supply the want; and, in response, we note the establishment, within the last few years, of separate departments of electro-chemistry, with a professor at the head devoting all his attention to that subject. At Leipzig, Dr. Ostwald; at Göttingen, Dr. Nernst; at Aachen, Dr. Classen; at Hanover, Dr. Kohlrausch; in Berlin, Professor Slaby and Dr. Vogel; in Munich, Prof. W. von Miller; in Darmstadt, Professor Kittler; in Amsterdam, Professor van 't Hoff; in Münster, Professor Hittorf; in Paris, Moissan. In the United States, Johns Hopkins University has under consideration the establishment of a chair of electro-chemistry, and will probably take the lead in this direction, as it has done in so many other useful innovations; and it is to be hoped that in the present brilliant plans for the extension of post-graduate study at the University of Pennsylvania, this promising field will not be overlooked.

In Germany, interest in electro-chemistry has become so general that the German Electro-Chemical Society (*Deutsche Elektrochemische Gesellschaft*) was organized in 1894. Sixty-five scientists signed the call for a meeting, which was held in Cassel on the 21st of April, when the society was duly organized. Dr. Ostwald was chosen first president, and what promises to become a most flourishing society was started with great enthusiasm. The first yearly meeting was held in Berlin, on October 5th and 6th, 1894. Bunsen, Kohlrausch, Hittorf and Wiedemann, the lights of electro-chemical science in Germany, were named honorary members. Ostwald delivered an able address on "Johann Wilhelm Ritter, the Founder of Electro-chemistry," and a number of other important papers were read and discussed. At the close of 1894, the society already numbered 290 mem-

bers, among whom were enrolled about a score of interested participants from this side of the ocean.

Within the past year there has also been founded at least one journal devoted exclusively to this new science, and three others which devote particular attention to it. The *Elektrochemische Zeitschrift*, a monthly journal, made its first appearance in April, 1894. It is published in Berlin, and has the co-operation of most of the prominent electro-chemists in Europe.

About the middle of the same month, the *Zeitschrift für Elektrotechnik und Elektrochemie* made its first appearance in Halle, and is now published semi-monthly. This journal, as its name indicates, gives equal attention also to electro-technics in general. It has been chosen as the official organ of the German Electro-chemical Society. The *Aluminum World*, published monthly in New York, since September, 1894, devotes special attention to electro-metallurgy, one of the most important branches of electro-chemistry. *L'Aluminium: Journal de L'Electrolyse*, is a journal of similar range, published monthly in Paris, and which has made its first appearance within a month (January 3d). With such exceptionally favorable facilities for spreading information in the German, French and English languages, not to speak of a host of other journals of chemistry, metallurgy and electricity, eager to reprint each item of value, every advance in electro-chemistry is sure of being at once made known to the industrial and scientific world.

If inquiry be made as to any recently-published standard books on electro-chemistry, it must be said that there is none which covers the whole ground. Ostwald's "*Elektrochemie—Ihre Geschichte und Lehre*" is in course of publication, but it treats of the purely scientific side of the subject. Dr. Gore's "Electric Separation of Metals" is the best work in English on electro-metallurgy; while Dr. Borcher's "*Elektrometallurgie*" gives a still more recent review of that part of the field, in German. In French, Tomassi's unwieldy volume, "*D'Électrochimie*," is a compilation of much valuable information thrown together in a rather disjointed way, but the reader will find recorded in it many

out-of-the-way facts which have escaped the other writers. Yet, many of the subjects which will be spoken of to-night are of so recent development that they have not yet found their way into the books, and allusion to them can be found only in the journals above mentioned. As the limits of a single lecture will only allow of a brief allusion to many interesting subjects, I give in each case references to the journals, which any one interested may consult for further information.

Electro-chemical Analysis.—Classen* has made a noteworthy contribution to this elegant method of analysis, by an exhaustive review of all his methods, giving in each case the concentration of bath, voltage, current density, temperature, etc., for best working. Such data were long needed, and this very thorough memoir marks an epoch in the history of electro-chemical analysis.

Batteries.—An entire evening would be necessary to describe all the newly-invented batteries. One, however, deserves special mention because of its applicability to electro-chemical experiments requiring high voltage. Warren† describes a cell, consisting of magnesium in a solution of ammonium chloride and copper in a solution of cupric chloride and hydrochloric acid. It is claimed for this cell that its electro-motive force is three volts, and that, because of its small internal resistance, it furnishes a current of great quantity. A single large cell, it is said, will run a sewing-machine. Warren claims that it gives a strong, constant current for a long time, and is certainly the most powerful cell known.

Theory of Electrolysis.—Ostwald and the investigators identified with the new school of physical chemistry, have industriously worked upon this subject. The theory of free ions in a solution has been elaborated. By this theory it is assumed that when a salt, such as potassium chloride, is dissolved in a large amount of water, part of the salt molecules are dissociated into free potassium and chlorine atoms

* *Berichte der Deutsch. Chem. Gesellsch.*, 1894, 2060. *Elektrochemische Zeitschrift*, November, 1894, 144.

† *Chemical News*, **70**, 179.

(ions), and that the current has a directive tendency only on these free ions. Salts which do not thus dissociate give solutions which do not conduct electricity; therefore, all electrolytes are composed of the salts which do dissociate. Further, all electrolysis of aqueous solutions is held to be primary; secondary reactions are regarded as an unnecessary complication of the explanation; the water is always primarily decomposed. Thus, a solution of potassium sulphate is supposed to contain, as free ions, hydrogen and potassium atoms and hydroxyl (OH) and sulphuryl (SO_4) groups. At the negative electrode, hydrogen is separated, and the hydroxyl groups left behind form potassium hydrate with the potassium ions in the solution; on the other electrode, hydroxyl separates, while the hydrogen atoms left behind form sulphuric acid with the sulphuryl ions in the solution.

The above explanation, I beg to observe, is a literal translation of Dr. Le Blanc's own words, and shows us how completely these theorists are begging the question. Your lecturer coincides entirely with the committee of the British Association for the Advancement of Science, that, while many remarkable facts have been recorded, and ingenious experiments made, by the German school, their explanations and theories are insufficient, misleading, and not warranted by the facts. The electrolytic dissociation theory is fundamentally opposed to the doctrine of the conservation of energy, and the attempts of the upholders of the theory to answer this objection satisfactorily, have been altogether futile; indeed, some of their so-called explanations are unworthy of serious attention.

O. Wiedeburg* has recently proven, by very careful experiments, that when the electromotive force at the electrodes is less than the voltage calculated as necessary for decomposition, a very small current passes through the solution, which increases slowly as the voltage increases, and rises very suddenly when the calculated voltage is reached. But the curve showing the quantity of current passing is not vertical at any point, although very steep in the neighbor-

Zeitschrift für Physikalische Chemie*, **14, 174.

hood of the calculated decomposing point. This would show that in the solution some molecules of the salt are bound together with a force less than the average for all the molecules, while others are bound together more strongly. It is only a confirmation of the Clausian theory of molecular motion, and in no sense proves the electrolytic dissociation hypothesis.

The reports of the Electrolysis Committee of the British Association for the Advancement of Science will be found to contain much healthy criticism of these new electrolytic theories.

Electricity Directly from Carbon.—E. E. Brooks* discusses what has been done in this direction. He dismisses thermo-couples with a very few words, as having too low an efficiency ever to be economical on a large scale. The only promising forms are cells using carbon as the negative plate. Nitre is unsuitable as an exciting liquid, because it acts too violently and too much is consumed for economy. The greatest stumbling-block, however, is the material for the positive plate. Platinum is too costly and other metals oxidise too easily. Brown found that by inserting a carbon rod in a Hessian crucible placed in a fire, and another carbon rod in the fire outside the crucible, a difference of potential of 0·2 volts was noticed between the two carbons. On putting nitre into the crucible, the voltage rose to 0·4, the crucible acting as a porous cell. Under similar circumstances, with melted potassium bi-sulphate in the crucible, voltage as high as 1·57 was obtained, and a current strong enough to run a bell. If a few drops of concentrated sulphuric acid were added from time to time, the current could be kept up as long as desired. Brooks concludes that in this case potassium pyrosulphate is the electrolyte.

Ostwald records this experiment: Two vessels containing water are connected by an inverted **U**-tube. In one is placed a platinum electrode, and in the other a zinc electrode, and these are connected by a wire running through a galvanometer. On adding some sulphuric acid to the

**Elektrochemische Zeitschrift*, 1894, 124.

water surrounding the zinc, brisk chemical action begins, but there is no current in the wire. On the other hand, if the acid be added to the water surrounding the platinum, gas is liberally evolved at the platinum electrode and a strong current is set up in the wire. From this experiment, Ostwald argues that in order to get the full effect of the chemical action converted into electricity, in Jablochkoff's cell (iron and carbon in fused nitre), the oxidising material should be around the iron only, and not in contact with the carbon.

In the future carbon cell, the oxidising material will not be around the carbon, but around the non-oxidising electrode. A cell properly constructed on these principles could burn carbon like an ordinary stove, but what is wanted before we can construct it is a suitable electrolyte, which will act merely as a medium or conveyor of the oxygen, and which will not be consumed. The solution of this problem does not appear impossible.

Borchers* attacks the question from another direction. He argues thus: "It is practically impossible to oxidise carbon satisfactorily in a cell and obtain its energy of oxidation as electricity. The gasification of the coal to carbonic oxide and the subsequent oxidation of this combustible gas in the cold, is the first rational step toward obtaining the electric current." Borchers, therefore, directs his investigations toward a cell in which carbonic oxide is dissolved in a menstruum, and in that condition is oxidised. A solution of cuprous chloride dissolves oxygen, carbonic oxide and hydrocarbon gases. A cell is therefore constructed containing this solution, dipping into which are two copper tubes serving as + poles, and through which carbonic oxide is forced into the solution. Between these is an inverted carbon bell, into which is pumped air, and which serves as the — pole. An electromotive force as high as 0·4 volts is obtained, whereas the oxidation of carbonic oxide should give 1·47 volts. A very feeble current, however, is obtained from a large cell. The correct theory of the chemical

* Report of the first yearly meeting of the German Electro-Chemical Society, October 6, 1894.

actions occurring is not beyond doubt, and the cell is at present very far from being successful in an economic sense.

This gas element has attracted wide attention. Already, L. S. Powell* has suggested an improvement. The carbon electrode is heated red-hot in the air for a short time, giving it a mossy coating, which absorbs oxygen more readily, and makes its action as a porous cell much stronger.

Ozone.—Dr. Fröhlich† reviews the production and utilization of ozone. Siemens and Halske produce it cheaply in large quantity by passing through air the silent discharge of a very high potential alternating current. Two metal tubes are taken, one placed inside the other, insulated from each other by strips of mica, and air is passed between them while the discharge passes from one tube to the other. Or, two thin glass tubes are placed within a third. Inside the inner one is water; between it and the next is the air space, and between the second and third again is water. The two water poles are made the terminals of the current. The ozone thus made is used for disinfection, bleaching wax, oils and sugars, restoring the taste to alcoholic liquors, purifying tobacco and coffee, and for making nitric acid. It is stated that a method has been discovered, and which will soon be published, whereby nitric acid can be made directly from moist air in the ozone tube.

Purification of Drinking Water.—G. Oppermann‡ affirms that "since all natural water contains small quantities of different salts, these can be resolved into their constituents by the electric current, and, under certain conditions, form ozone and hydrogen peroxide, which purify the water by destroying the organic impurities and lower organisms. It is now established that, under proper conditions, water can be completely sterilized by the electric current. The organic impurities can be so completely removed that treatment in the chemical way will show no trace of organic

* *Electrical Review*, December 7, 1894.

† German Electro-Chemical Society, first meeting, October, 1894.

‡ *Elektrochemische Zeitschrift*, September, 1894. *The Aluminum World*, March, 1895.

matter, and bacteriological tests by gelatine cultures will show no trace of micro-organisms." Oppermann first passes the current through with platinised electrodes. The ozone and hydrogen peroxide left in the water give it an unpleasant taste, to remove which the water is again electrolysed with aluminium electrodes. Precipitated hydrous alumina is formed, which completely clears the water, the glue-like material enveloping the finest suspended particles, entangling and carrying them down with it. In this operation, a current of low voltage and large quantity is used. The precipitate is filtered out, calcined and sold as alumina.

Dr. Lugo simplifies the matter by electrolysing only with aluminium electrodes. This causes a greater consumption of aluminium, but not enough to interfere with the practicability of the process, and the work is done in one operation. The apparatus consists of a trough in which are placed alternately zinc and aluminium electrodes, the latter being the anodes. Water flows continuously through the trough, underneath each aluminium plate and over each zinc plate, passing out at the other end. It is then filtered to remove the alumina. The apparatus can be constructed on any desired scale, and it is reported that plans have been drawn for a plant to purify Passaic River water for the supply of Jersey City, to the extent of 30,000,000 gallons daily.

Purification of Salt-spring Brine.—The usual impurities are the bicarbonates of iron, calcium and magnesium, calcium chloride and sulphate and magnesium sulphate. Collins* passes through it a current of 2·5 volts, which does not affect the common salt, but renders the impurities insoluble. Calcium bicarbonate, for instance, splits up into calcium hydrate (precipitated) and carbonic acid gas, while the latter precipitates more of the bicarbonate as carbonate; the reactions are

$$CaH_2(CO_3)_2 = Ca(OH)_2 + 2CO_2$$
$$CaH_2(CO_3)_2 + CO_2 = CaCO_3 + H_2O + 2CO_2$$

Disinfection of Sewage.—Hermite's process of electrolysing sea-water with the formation of magnesium hypochlorite,

* *Wagner's Jahresbericht*, 1892, 326.

and running this into the sewage, has been subjected to a thorough test at Worthing, England. The medical officer of the local Health Board says, in his report, that there is no instantaneous decomposition of fecal matter, and no complete sterilization of the sewage, and recommends, as an improvement, the passing of the electric current directly through the sewage itself, 2·5 to 3 volts being sufficient to kill all ordinary bacilli.

At Brewsters, New York, the Hermite process has been adopted, however, with great satisfaction.* A current of 700 ampères and five volts is sent through sea-water as it flows slowly between four carbon cathodes (each one foot square), and three platinised copper anodes. The rate of flow is so regulated that the solution is electrolysed to the proper degree, and then is caused to overflow directly into the sewer. The disinfection is practically complete. Comparative tests show that the solution equals in effective strength a one per cent. solution of chloride of lime, which latter would cost 1·4 cents per gallon, while the electrolysed sea-water costs only 0·01 cent.

The process is thus proved to be satisfactory for treating ordinary dilute sewage, but the English tests show that it does not completely sterilize concentrated sewage.

Bleaching.†—Hermite's process consists in decomposing a solution of magnesium chloride, the resulting hypochlorite being allowed to act, either directly on the substance to be bleached, and which is placed in the electrolyser, or by being drawn off, and the bleaching done in a separate tank. The process is in general use abroad, and, to a limited extent, also in the United States. Animal fibres cannot be subjected to this mode of bleaching; it is most usually applied to cotton, linen, hemp, jute and paper pulp. In treating wood pulp, it is subjected to the action of a hot solution of common salt, under pressure, while the electric current is simultaneously passed through. This is effected in a strong digester, patented by Kellner. Electrolytic bleaching costs about one-half as much as the old method with chloride of lime. The

* *Journal American Chemical Society*, January, 1894.
† *Journal of the Franklin Institute*, **139**, 177.

electric current which lights the works at night can be run during the day through the electrolysers.

Dr. Goppelsroeder* reviews the applications of the electric current made by him during the last twenty years, to the production, changing and destroying of coloring matters. He shows how some organic colors are bleached by the current, others changed, and others produced from non-coloring material. By using electrodes of any desired design, acting on fabric saturated with dye, different colored designs are obtained. Or, if the fabric be saturated with a suitable electrolyte, patterns can be bleached upon it in the same way.

Tanning.—Groth† utilizes electricity in tanning by fastening the raw hides on a barrel, which is caused to revolve on a vertical axle, thus forming a cylinder, whose outer surface is pressed upon by a number of long, vertical rollers carrying the current, which is taken away by plates attached to the rollers. The rolling and squeezing force the tannin into the leather, while the electricity facilitates the absorption of the tanning material. During 1894, a plant using this process was started at Orbe, Switzerland, having a weekly output of 300 finished skins.

Purification of Sugar Syrup.—If an impure sugar syrup be subjected to electrolysis, the organic coloring matters are destroyed by oxidation, and many of the inorganic salts present may be removed by using suitable electrodes. Schollmeyer, Behm and Danmeyer‡ heat the syrup to 70° or 75° C., in vessels holding 1·5 cubic meters, and pass a current of 50 to 60 ampères at a tension of 4 volts to each vessel, using electrodes of zinc or aluminium, having a total surface of 12 to 14 square meters. The negative pole soon becomes covered with a gummy coating, which is almost pure albumen, and increases the electrical resistance, to avoid which the current is reversed every two or three minutes. The current is applied only eight to ten minutes, at the end of which time the syrup is run out into a vat and treated

* *Elektrochemische Zeitschrift*, April, 1894, 3.

† *Elektrochemische Zeitschrift*, October, 1894, 134.

‡ German Patent, No. 76,853 (1894).

in the usual way with milk of lime. The advantages of the electrical treatment are that less milk of lime is needed, and that the use of bone charcoal is done away with. The zinc or aluminium anodes are attacked, forming alkaline salts, which precipitate the impurities of the sugar, while the gummy aluminium hydrate brings down all suspended impurities. Daix* states that one electric horse-power will suffice to refine daily the syrup from 100 tons of beet root, and that the process is in successful use in several of the German refineries.

Bacteriological Experiments.—Smirnow and Klemperer† have made some remarkable experiments concerning the action of electricity on virulent bacteria cultures. It has been proven that when active bacilli of consumption and cholera are subjected to electrical action, the electrolysed liquid gives immunity against fatal quantities of the same bacteria. It has not been proven that it will act as an antidote after the fatal poison has entered the system. Smirnow electrolysed albumin cultures of diphtheria poison, and found at once that, although all the bacilli therein are not killed, yet the liquid thus produced gives immunity to the system against the virulent poison. Experiments with dogs and rabbits have been conclusive, and the medical profession is hastening to apply the serum thus produced in actual practice. The possibility of extending this principle to the treatment of all germ diseases is one of the great questions of modern medical science.

Manufacture of Chloroform.—The electrical method is so cheap and expeditious that it is rapidly displacing all others. An enameled-iron retort is used, having a double bottom by which it is steam-heated. Two lead plates form the electrodes. A twenty per cent. solution of common salt is placed in the retort, brought to the boiling point; the current is caused to flow, and *acetone* is then passed continuously through the electrolysed solution. The free chlorine generated by the electrolysis of the salt acts on the acetone, forming chloroform, which distils off and is collected in a

* *Elektrotechniker*, 1894, 201.

† *Berliner Klinische Wochenschrift*, 1894, 683–742.

suitably attached condenser. Chloroform thus prepared contains no foreign chlorine compounds, and the return per 100 parts of acetone is 190 parts of chloroform out of a possible yield of 206 parts.

Aniline Colors.—The use of the electrical current to produce oxidations and reductions in the manipulation of organic substances, particularly in producing dyes, has been carried so far that it is impossible to attempt even to enumerate them here. In general, the electrolyser is divided into two parts by a porous partition, and, if oxidation be the objective point, the liquid is placed in the anode compartment; or, if reduction, then in the cathode cell.

Cadmium Yellow.—This valuable pigment is easily made by electrolysing a solution of common salt with cadmium electrodes, at the same time leading a current of sulphuretted hydrogen into the solution. Cadmium sulphide is continuously precipitated as quickly as cadmium chloride goes into solution, the pigment being of different shades, according to the conditions of the electrolysis.

Antimony Vermilion.—Chemically, this pigment is antimony sulphide, and may be prepared electrolytically in a manner in all respects similar to that employed in making the cadmium compound, except that antimony electrodes are used.

*Vermilion.**—The following process for preparing mercury sulphide has been described. A wooden tank, one meter high and two meters in diameter, is provided with a shelf near the bottom, on which are placed saucers containing mercury, connected with the positive pole of a dynamo. The negative pole is a *steeled* copper plate lying on the bottom. The liquor placed in the tank contains eight per cent. each of ammonium and sodium nitrates. A perforated coiled tube conveys sulphuretted hydrogen into the tank, and an agitator keeps the whole in motion. From time to time the precipitated vermilion is filtered out.

Scheele's Green.—An eight per cent. solution of sodium sulphate is electrolysed with copper electrodes. The bath

* *La Lumière Électrique*, 1894, **52**, 376.

is heated by a steam coil, and a little sack containing white arsenious oxide is suspended in the liquid. The current forms copper sulphate and caustic soda. The latter dissolves the arsenic to sodium arsenite, which at once precipitates the copper sulphate as copper arsenite, regenerating sodium sulphate. The process is made continuous by renewing the arsenic and the copper plates, and straining out the precipitated pigment.

Mitis Green.—If the arsenious oxide be replaced by arsenic pentoxide, copper arsenate is precipitated. For this purpose a solution of the oxide is allowed slowly to trickle into the bath around the negative electrode. One electric horse-power produces about one-fifth of a kilo of pigment per hour.

Japanese Red.—This pigment is a lead oxide colored by eosin. It is made electrolytically by electrolysing a ten per cent. solution of sodium acetate with lead plates, an eosin solution being run in continuously during the operation. The precipitated lead oxide takes up the coloring matter as it is forming, and the product is separated by decantation. Rhodamin may be used instead of eosin, and zinc electrodes in place of those of lead.

*Prussian Blue.**—Goebel precipitates a solution of potassium ferrocyanide by means of a ferrous salt, such as copperas; suspends the precipitate in water and electrolyses it. The solution is acidified with five per cent. of an acid and put into the anode compartment of the electrolyser. If the action be prolonged the blue color becomes faint, and the product finally passes into a dark Berlin green.

White Lead.—Stevens† electrolyses a fifteen per cent. solution of nitric acid with lead electrodes, passing in continuously a current of carbonic acid gas. The lead carbonate is precipitated continuously. Ferranti, of London,‡ uses a solution of ammonium acetate and encloses the anodes in porous cells. The electrolysis yields a solution of lead acetate at the anode and caustic ammonia at the cathode.

* *Engineering and Mining Journal*, January 19, 1895.

† French Patent, No. 216,265 (1892).

‡ English Patent, No. 23,572 (December 21, 1892).

These solutions are run out into separate tanks, and the ammonia is carbonated by running carbonic acid gas into it. The solution of ammonium carbonate is then mixed with that of lead acetate, precipitating white lead, and leaving ammonium acetate in solution to be used over again. This precipitation is performed with the solutions hot. The electrolyser consists of lead plates locked together in a frame, as in a filter-press, the frames being insulated from each other by porous diaphragms of stout Willesdenized paper.

This process, or one similar to it, is already in operation on an experimental scale at the works of one of the largest lead-paint makers in Philadelphia.

Caustic Alkali, Soda and Bleaching Powder.—The practical electrolysis of a strong solution of common salt, producing caustic soda and chlorine gas—the former being used for making carbonate of soda, and the latter, bleaching powder—is of very recent development. On passing the electric current through strong brine the salt is decomposed, caustic soda forms around the cathode and chlorine is set free at the anode. The substances decomposed and the heat absorbed are as follows:

	Calories.
1 molecule of salt in solution (Na, Cl, H_2O)	96,510
1 molecule of water (H_2O)	69,000
Sum	165,510
The substance formed and heat developed are:	
1 molecule of caustic soda in solution (Na, O, H, H_2O) . . .	111,810
Deficit of heat	53,700

$$\text{Voltage required } \frac{53,700}{23,000} = 2{\cdot}33 \text{ volts.}$$

The practical difficulties encountered in this operation are to find an anode which will not disintegrate rapidly under the combined attack of nascent chlorine and oxygen, and to construct a porous diaphragm which will keep the caustic soda around the cathode from re-combining with the chlorine around the anode.

Greenwood saturates carbon anodes with tar and bakes them at a high temperature. Castner embeds the carbons in powdered carbon and heats them white hot with an electric current, changing them into graphite, which is more resisting. Höpfner claims that both anodes and cathodes can be replaced by ferro-silicon, cast into any desired shape.

Riekmann and Le Seur use a porous partition made of parchment paper soaked in blood and coagulated, the albumin forming the body of the diaphragm. Le Seur uses the expedient of a double diaphragm, into the centre of which the fresh brine is run a little faster than it filters through. The level of liquor in the diaphragm is thus kept higher than in the cell, and as the solution flows both ways into the anode and cathode compartments, a mixing of the liquors in these compartments is thereby prevented. Hargreaves uses a screen of fine copper wire on which asbestos fibre has been deposited. This is said to be the best diaphragm yet used, lasting well and having very low resistance. Hermite has proposed a horizontal diaphragm of mercury, supported on gauze of asbestos or other non-conducting material. Castner uses a movable mercury diaphragm, which will be described in detail.

Kellner avoids the re-combination of caustic soda and chlorine by introducing carbonic acid gas into the cathode liquor and precipitating the soda as bicarbonate. Parker and Robinson propose, since the caustic is largely used in making soap, that fatty acids be introduced into the cathode cell, when the soap produced by the caustic acting on them, floats, and may be skimmed off.

H. Y. Castner, of New York, has patented the following ingenious apparatus:* A shallow vessel is divided into three compartments by two partitions reaching from the top nearly to the bottom. The outer cells are closed by tight lids. Mercury is placed in the bottom, deep enough to reach the partitions and isolate the three compartments. In the outer cells a strong brine solution is kept circulating, and in this are placed carbon anodes, close to the surface of the mer-

**Engineering and Mining Journal*, September 22, 1894.

cury. Pure water circulates in the middle cell, into which dips an iron cathode. On passing the electric current, the mercury in the outer cells acts as a cathode, and absorbs metallic sodium, while chlorine gas is set free at the carbon anodes and passes into a gas main in communication with the cover. The sodium diffuses into the mercury in the centre cell, the diffusion being assisted by a slight rocking motion given to the whole vessel by a suitable mechanism. In this cell the mercury acts as anode and the iron plate as cathode. The water is decomposed, hydrogen gas is set free at the cathode, while the oxygen liberated at the anode (the mercury) oxidises the sodium in it to Na_2O, which combines with water to form caustic soda. The mercury rarely contains at any time over 0·2 per cent. of sodium. The fittings to each vessel are pipes to the outer cells to circulate fresh brine, a gas main to take away chlorine, and pipes to the inner cell to supply water and take away the caustic solution, which only needs evaporation to be in marketable shape. The plant now in operation at Oldbury, near Birmingham, England, consists of 30 decomposing vessels, a dynamo giving 550 ampères at 120 volts (4 volts to a cell), run by a 110 horse-power engine. The daily output is 1,200 pounds of pure chlorine gas and 1,000 pounds of 99½ per cent. caustic soda. The plant was put in operation in July last, and probably marks the beginning of an immense industry.

Electrolytic soda plants are springing up all over Europe, wherever cheap raw materials (salt, limestone, coal) are available, and particularly where water-power can be had. Already the combined output is nearly 100,000 tons yearly, and Lunge, the Mentor of the soda industry, has given it as his opinion that it is only a question of a few years when the historic *Le Blanc process* and the ingenious *ammonia process* will be entirely eclipsed.

Potassium Chlorate.—By electrolysing a hot solution of potassium chloride, and allowing a free mixture of the caustic potash, chlorine and oxygen produced, potassium chlorate results, the reaction being

$$KOH + Cl + O_2^{\cdot} = KClO_3 + HCl$$

F. Hurter recommends that the solution be electrolysed in a metallic vessel which itself forms the cathode, the anode being formed of thin sheets of platinum. Haussermann and Nachold* hold it the best practice to use a porous cell enclosing the anode, around which circulates a solution of caustic potash, while potassium chloride solution is used outside. The chlorine and oxygen set free at the anode convert the caustic into chlorate, while the chloride solution is gradually converted into caustic. Strong solutions, a temperature of 80° C., and platinum anodes give the best results.

About 2,000 tons of potassium chlorate are used yearly for making safety matches. The *Societè d'Electrochimie* at Vallorbes, in the Jura Mountains, Switzerland, operates an electrolytic plant of 2,000 horse-power, and produces yearly 600 tons. The *Superphosphat Aktien Gesellschaft* has erected a 6,500 horse-power plant at Mansboe, in Dalecarlia, Sweden, and at the present time it is probable that all the potassium chlorate marketed is produced by the electrolytic method.

Chromic and Similar Acids.—Placet and Bonnet, of Paris,† produce chromic acid by electrolysing alkaline chromate or bichromate in solution, using carbon electrodes. The cathode is placed in a porous cup filled with pure water, the anode in the chromate solution. Caustic alkali forms around the cathode, and is replaced from time to time by pure water. Chromic acid forms in the outer vessel, and may be crystallized out of the solution. The caustic alkali solution may be utilized to act on chromium minerals to produce the chromate. This principle may evidently be adapted to the treatment of other acids combined with alkaline bases, or, in general, for extracting pure acids from binary compounds.

Phosphorus.—Readman and Parker's‡ electric process is used by the Electric Construction Corporation, at Wednesfield, England. A mixture of calcium acid phosphate and carbon is heated to whiteness in an electric furnace, between

* *Journal of the Society of Chemical Industry*, September 29, 1894.

† English Patent, No. 22,819 (December 12, 1892).

‡ *Industries*, 1892, 163.

carbon electrodes, and the phosphorus distilling off is caught in a condenser. In the plant now working, an alternating current of 400 kilowatts is used. The intense heat makes the reduction much more complete than in ordinary retorts, the slag remaining containing only a small amount of phosphorus as silico-phosphide of iron, the lime having formed calcium silicate, aluminate and carbide. Albright and Wilson are said to have secured possession of the patents, and will work the process.

Carborundum.—This is the name of a recent product of the electric furnace, a silicon carbide, having the composition CSi. Mr. E. G. Acheson* first made it by heating fine carbon and clay between carbon poles in an electric furnace. Thinking that it was a compound of alumina and carbon, he named it accordingly, in allusion to its presumed resemblance to a combination of carbon and corundum. It is a green, crystalline compound, and so extremely hard that it has found wide practical application as an abrasive material. Made up into wheels it is found to have better wearing qualities than emery, and the fine dust can be used for polishing precious stones and even the diamond. The Carborundum Company, of Monongahela City, Pa., produced, in 1893, 15,000 pounds of this material, which sold at $4 per pound. During 1894, a German works was started at Iserlohn.

The method of manufacture is briefly as follows. A mixture is made in the proportions—

	Parts.
Sand	182
Coke	146
Salt	72

This will produce 100 parts of carborundum.

Two hundred pounds of the mixture are placed in a fire-brick-lined cavity, 6 feet long, 18 inches wide and 12 inches deep. Four carbon electrodes at each end supply the current, and a core of carbon dust starts the arc from one end to the other. The current from a 100 horse-power dynamo is sent through for eight hours, three charges being run per

* *Journal of the Franklin Institute*, **136**, 194.

day. The silicon carbide found between the electrodes is treated seven days with dilute sulphuric acid to remove iron, and is then ready for sorting and working into wheels, etc. The company enlarged its works in 1894, and is doing a flourishing business, the product having gained the reputation of being the best abrasive known.

Calcium Carbide.—This is another recent product of the electric furnace. T. M. Willson,* of Spray, N. C., in the course of experiments to produce alloys of calcium and aluminium, succeeded in forming a black, brittle, fusible substance, which chemical analysis showed to be calcium carbide (CaC_2). From a mixture of

	Pounds.
Burnt lime	2,000
Fine coal dust	1,200

and with the use of 180 electric horse-power for twelve hours, Mr. Willson claims to be able to produce 2,000 pounds of calcium carbide, at a cost approximating $20. This substance promises to be of great industrial value from the curious reaction it gives with water:

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2.$$

In other words, it is converted into calcium hydrate, giving off acetylene gas in the proportion of 100 parts of gas to 247 of calcium carbide, which would mean, approximately, 10,000 cubic feet of gas per ton of carbide. This gas has the highest illuminating power of any known hydrocarbon, and, when mixed with half its volume of air, can be burned without smoking, giving a flame five or six times as brilliant as ordinary illuminating gas. It has been claimed that this gas, equal in illuminating power to coal gas of 25 candle-power per five-foot burner, can be made at a cost of 30 cents per 1,000 cubic feet.† Other and even more important uses for this gas may be found in the field of technical chemistry. For example: by passing electric sparks through a mixture of acetylene and nitrogen, hydrocyanic

* *Engineering and Mining Journal*, December 15, 1894; *this Journal* **139.**, 321.

† Mr. Willson's present claims are much more radical even than this.—Ed *J. F. I.* See this *Journal*, **139**, 321 *et sig.*

acid is formed, from which cyanides can be made. By heating in a sealed tube, it passes into benzene. By an indirect process it can be made to yield alcohol. The difficulties which the projectors are now seeking to overcome are: the danger of explosion of the gas mixed with air, and the decomposition of the carbide by the action of the atmospheric moisture.

Cleaning Metallic Surfaces.—The operation of pickling has been improved by the use of electrolysis. The articles are immersed in dilute sulphuric acid opposite to a negative pole of carbon or wire-gauze, electro-plated with silver and preferably covered with platinum black. On connecting electrically the articles with these poles, by a wire outside the bath, gas is disengaged at the silvered surfaces, while the articles are rapidly and uniformly corroded. If a little nitric or chromic acid be added to the bath as a depolariser, no offensive odors are given off. Another method is to use as a bath, a salt of the metal to be pickled, and an external electric current. The articles to be pickled being used as anodes, they are rapidly corroded, the metal being deposited on suitable cathodes, while the bath remains constant. This method has the great advantage of dispensing with the use of fresh acid, and will doubtless come into extensive use.

THE METALS.

Aluminium.—No very recent improvements have been made in the electrical processes for extracting this new metal. It is now made exclusively by the electrolysis of alumina dissolved in a bath of the fused fluorides of aluminium and sodium, the dissolved alumina being decomposed while the solvent salts are unaffected by the current. The principal works are those at the Rhine Falls, in Switzerland, using 4,000 horse-power, and making three tons daily by Hèroult's process; and the Pittsburgh Reduction Company, making one ton daily by Hall's process. The latter company will presently start a new and much larger plant at Niagara Falls, beginning with a daily output of two tons, which within a year may be increased to four tons. The total output of aluminium in the world, in 1894, was 1,020 metric

tons; the present selling price is thirty-five cents per pound in Europe and fifty cents in the United States. The Swiss works intend extending to 15,000 horse-power within the next five years, when the European price will probably fall to twenty-five cents per pound. The wonderful development of the electro-metallurgy of aluminium is one of the most striking achievements of modern electro-chemical science.

In the utilization of this metal, Mr. J. D. Darling, of Philadelphia, has gained celebrity by electro-plating 100,000 square feet of ornamental iron work on the tower of the new Public Buildings of that city. The question as to whether aluminium could be electro-plated on another metal at all was a doubtful one until Mr Darling began work on this *tour de force*. The chemical composition of the bath used is kept as a trade secret. The columns, etc., to be plated are first coated heavily with copper, in the ordinary way, and then coated over with aluminium one-sixteenth of an inch thick. This last operation takes seventy-two hours, the current used averaging ten ampères per square foot of anode surface, and seventeen ampères at the depositing surface, an electro-motive force of eight to ten volts being used to each bath. Specimens of the work which I have seen are very well done, and reflect great credit on the skill of this Philadelphia electro-metallurgist.

Antimony and Arsenic.—Electrolytic processes for reducing these metals from their ores have been devised, but I cannot say whether they are in practical operation. Siemens and Halske* treat the natural sulphides of these metals with solutions of alkaline sulphide, in which they are soluble, forming alkaline double sulphides. The solution is then electrolysed, separating out the arsenic or antimony and leaving an alkaline sulph-hydrate in solution. The reactions would be

$$\text{(Solution)}\quad Sb_2S_3 + 6NaHS = Sb_2S_33Na_2S + 3H_2S.$$
$$\text{(Decomposition)}\quad Sb_2S_33Na_2S + 3H_2O = Sb_2 + 6NaHS + 3O.$$

Diaphragms separate the vat into anode and cathode cells, the positive poles being of carbon or platinum.

* German Patent, No. 67,973.

Chromium.—Pure, metallic chromium is now obtainable in large quantities. It is made by the electrolytic process of Placet and Bonnet.* To a dilute solution of a chromium salt are added the sulphates or chlorides of the alkalies or alkaline-earths; also, certain organic substances, such as gum arabic or dextrin. The solution is one-fifth saturated with the chromium salt and four-fifths with the other substances. The solution is warmed; a cathode much smaller than the anode is used to give great current density at the depositing surface without requiring excessive power, and a current at thirty to forty volts is used for decomposition. To make chromium alloys, the salt of the alloying metal is added to the solution in about equal quantity to the chromium salt. With a low voltage, only the alloying metal (as iron) separates; with higher voltages increasing amounts of chromium are deposited with the other metal, so that any desired proportions can be obtained. Or, the alloying metal may be first deposited alone by using a low voltage, then the desired quantity of chromium by a higher voltage, and the whole plate melted down to form the alloy.

Manganese, Tungsten, Chromium.—Moissan† has found the oxides of all these metals easily reducible in the electric furnace. A current of 300 ampères at 60 volts, passed for six minutes through a mixture of manganese oxide and carbon, gave 100 to 120 grams of manganese, containing from 6 to 14 per cent. of carbon, according to the excess of carbon present. The same current, passed for ten minutes through a mixture of chromium oxide and carbon, gave 100 to 110 grams of chromium containing from 8·6 to 11·9 per cent. of carbon. By mixing this chromium carbide with fresh chromium oxide and heating it again in the furnace, the carbon was eliminated and pure chromium was obtained. Tungstic acid in the same manner gives tungstic carbide, with 17 to 19 per cent. of carbon, which can also be reduced to pure tungsten by heating with more tungstic oxide.

Copper.—The electrolytic refining of copper is now carried on commercially on an immense scale. There are two

* *The Mineral Industry*, 1893, 560.

† *Comptes rendus*, **116**, 349, 1225.

single plants in the United States, at Baltimore, Md., and Butte, Montana, which have a daily capacity of fifty tons each. In 1894, over 50,000 tons of copper were refined in the United States, and the time is probably not far distant when the whole copper production will be electrolytically refined. The cost of refining at the new Anaconda plant, at Butte, Montana, under the direction of Mr. Thofehrn, is said to be only 0·6 cents per pound. An innovation in the practice of these works is the removal of ferrous sulphate from the solution by warming it and blowing air through, when the iron precipitates as basic sulphate. It is stated that Lake Superior copper is not of as good quality as formerly, because of poorer ores and closer working, and that the Calumet and Hecla Company contemplates changing its smelting plant at Buffalo into an electrolytic plant located at Niagara Falls, where power can be rented at $7 to $10 per horse-power per year. The copper thus refined will command a higher price, and, at the same time, the silver contained in it can be extracted.

Gold.—Münster* claims that he has found in the sea water of Christiania Fjord, twenty milligrams of silver and six milligrams of gold to every 100 cubic meters of water. He proposes to extract these by immersing galvanised iron electrodes in the channel, and passing through them an electric current of feeble tension.

In the cyanide process of treating gold ores, the gold is dissolved in a solution of potassium cyanide. To extract it from this solution, an electrolytic process has been found advantageous. The electrodes must have a large surface; lead is used for the cathodes and iron for anodes; carbon anodes disintegrate too quickly. To precipitate the metal from 100 tons of cyanide solution carrying five dwts. of gold per ton in twenty-four hours, requires 10,000 square feet of cathode surface, and a current of 600 ampères at four volts tension. The iron plates form Prussian blue, but they last a long time. The anodes are placed vertically, and are covered with canvas to keep the Prussian blue out of the

Engineering and Mining Journal*, **53, 570.

liquid. The lead sheets stand between, with 1·5 inch space between the electrodes. The electrolysing boxes are covered and kept locked, being opened once a month, when the lead plates are lifted out and melted down. They carry two to twelve per cent. of gold, and are cupelled. The expenses are three shillings per ton of liquor treated, and on a large scale it can be reduced to 2·5 shillings; whereas, the ordinary method of precipitating by zinc costs four shillings.*

Parting Gold and Silver.—The Moebius† electrolytic process is used by the Pennsylvania Lead Company, near Pittsburgh, and by the St. Louis Smelting Company. The alloy of gold and silver is cast into anodes, and used in a ten per cent. solution of nitric acid. A current of 1·4 volts per cell is used, and a current density of twenty-six ampères per square foot. The plant at Pittsburgh consists of forty-two cells, run by a current of 180 ampères by sixty volts, there being seven square feet of anode surface in each cell. The output is 20,000 ounces of silver per day. The anodes contain 987 parts silver, 6·3 parts gold, 6·7 parts copper. The deposited silver contains a little copper. The slimes are melted down with silica and borax to an alloy averaging 650 parts of silver, and 300 parts of gold, the remainder being lead and copper. This rich alloy is melted with more pure silver and parted with nitric acid. It is said that this process is cheaper than the ordinary parting process, but one would hardly judge so from the description given.

Lithium.—Guntz‡ mixes anhydrous lithium chloride with an equal weight of potassium chloride, the mixture melting at 450° C., and electrolyses it with carbon anodes 8 millimeters in diameter, and iron cathodes 3 to 4 millimeters in diameter, enclosed in a glass tube, 20 millimeters inside diameter. By keeping the temperature low and using a current of 10 volts and 20 ampères, the lithium is separated and collects in the glass tube. It contains 1 to 2 per cent. of potassium, but is pure enough for most purposes for which it may be used.

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* *Elektrochemische Zeitschrift*, March, 1895.

† *Journal of the American Chemical Society*, January, 1894.

‡ *Comptes Rendus*, 1893, 732.

Magnesium.—This metal is now made only by electrolysis, the sodium method having been entirely displaced. The principal works are those of the Aluminium und Magnesium Fabrik, at Hemelingen, near Bremen. The process consists in the electrolysis of the fused double chloride of potassium and magnesium, reducing gases being introduced under the cover of the vessel to prevent the magnesium from firing. Recently, an alloy, called *Magnesium-Zinc*, has been introduced into commerce as a substitute for pure magnesium. It is an alloy of about 62 per cent. magnesium, 26 per cent. zinc, and 12 per cent. of iron. It is very brittle, can easily be reduced to powder, and is said to answer quite as well as pure magnesium in pyrotechny and photography, while it costs much less. The method of manufacture is to electrolyse the above-named fused salt in a crucible with molten zinc at the bottom for a cathode. In this way an alloy of magnesium with 30 per cent. of zinc is obtained. Some ferrous chloride is then stirred into the bath, which is at once reduced by the alloy, and the iron thus introduced.

Sodium.—Metallic sodium is now made only by electrolysis, and principally by Castner's process.* His works at Oldbury, England, use 1,000 horse-power, and have an output of from five to six tons weekly. A similar plant has recently been erected near Frankfort, Germany. The sodium produced is used either to make sodium peroxide for bleaching purposes, or in the manufacture of organic salts and dyes. The making of antipyrine by Dr. Knorr's patented process involves the use of sodium.

The process consists in the electrolysis of fused caustic soda, kept at a constant temperature of 313° C., in specially constructed cells, each cell taking 1,000 ampères of current and an electromotive force of only 4 to 4·5 volts. The efficiency is about 80 per cent. By keeping the temperature not more than 30° above the melting point of the soda, the electrical resistance is low, the operation proceeds uniformly and the sodium runs off from the top of the bath in a melted state. This last point is of especial advantage, as the distil-

* *Scientific American Supplement*, July 7, 1894, 15,435.

lation and condensation of the sodium, with all their attendant losses and dangers, are entirely avoided.

J. D. Darling and H. C. Forrest, of Philadelphia, propose* to electrolyse sodium nitrate in a similar manner at a gentle heat, obtaining the sodium melted, and, at the same time, passing the vapors produced at the anodes through water in Wolff bottles, and producing nitric acid. I have not yet learned whether this process is being practiced commercially.

Zinc.—Cassel and Kjellin, of Stockholm†, propose the following process of extracting zinc from its sulphide ores. The ore is roasted as far as possible to soluble zinc sulphate, which is leached out. The electrolysing vessel has a porous partition; around an iron anode is placed a solution of sulphate of iron, while the zinc sulphate solution surrounds the cathode. On passing the current, zinc is deposited from the latter solution, while its equivalent quantity of acid is separated at the iron anode and dissolves it to sulphate. The electromotive force of decomposition, under these circumstances, is the difference between that required to decompose zinc sulphate and that of the iron sulphate, or about one-third of a volt, thus allowing the separation of zinc without decomposing the water of the solution. The process is very pretty in theory, but the porous partitions will be likely to give trouble in practical working, and the question of the cost of the iron used and the market for the copperas produced form large factors in deciding the economy of the process.

Heinzerling proposes to roast zinc ores completely to oxide, and dissolve this out by a concentrated solution of magnesium chloride. This solution is then electrolysed, the zinc separated out, and the magnesium chloride solution used over again. Solution of the zinc oxide is effected hot, under two or three atmospheres pressure. A current of 200 ampères per square meter is used for electrolysis, while the solution is kept as cold as possible.

Galvanising sheet iron by electricity has again been tried, this time at the works of Watson, Laidlaw & Co., Glas-

* English Patent, No. 5,808 (March 20, 1894).

† German Patent, No. 67,303 (1893).

gow, Scotland. The depositing bath contains zinc oxide dissolved in caustic potash, kept warm, and the sheets are kept in motion. The metal is deposited for five to twenty minutes, at the rate of 34 to 134 grams per square meter per minute.

Your lecturer has conducted an extensive series of experiments in refining impure zinc by electrolysis. By using a current density of 100 ampères per square meter, at 1·3 volts tension per bath, and keeping the solution agitated by mechanical means, thick deposits of zinc of exceptional purity can thus be obtained. The accumulation of iron in the solution is prevented by blowing air through it continually, which oxidizes and precipitates the iron as basic sulphate, that can be separated by filtration. There is considerable loss in melting down the zinc sheets to ingot shape; but, notwithstanding this, the process could be operated commercially but for the very low price which zinc has reached within the last few years, the margin for profit being less than in refining copper, while the expenses are greater.

ELECTRICITY DIRECTLY FROM COAL.*

By Alfred H. Bucherer.

The endeavors of scientists and inventors to convert directly the potential energy of coal into electrical energy have received a fresh incentive from the interesting experiments of Dr. Borchers. So alluring are the rewards that follow the solution of this problem that men known for their conservative attitude in similar questions have hailed with extravagant expressions of delight the seeming results of the German electro-metallurgist. It is true the latter deserves high credit for testing his ingenious idea; yet from his own account of the facts brought out in his experiments, I feel sure that as yet his endeavors have been fruitless. Such failure, it is only just to note, could not have been

* To be read at the stated meeting of the Electrical Section, March 26, 1895.

foreseen from the standpoint of our present knowledge of electro-chemistry. In the extensive discussion of Dr. Borchers' work, which appeared in various technical and scientific journals, one point has been altogether ignored, and this point is of such essential importance in the problem of the conversion of the potential energy of coal into electric energy that it deserves to be fully elucidated. This point is the relation of chemical to electrical energy. Dr. Borchers erroneously supposed that it would be possible to obtain an amount of electrical energy from the reaction $2CO + O_2 = 2CO_2$ that would be equal to the heat of formation of as much of the quantity of the reacting substances as take part in the transformation. Since v. Helmholtz has shown that such a view does conflict with facts, it is no longer legitimate to assume its correctness, still less to base upon it efficient calculations, as was done by Dr. Borchers and Ostwald (see *Zeitschrift f. Phys. Chem.*, 1894, p. 521).

The maximum amount of work which we can derive from a chemical reaction is a definite quantity, and is independent of the kind of energy into which it is transformed. Suppose we have an unpolarizable cell and make the external resistance extremely large as compared with the internal resistance; then, if the quantity m of electricity has passed through the circuit, a proportional amount of chemical action has occurred, and the heat developed in the external circuit is equal to the electrical energy obtained. On examination we will find now that although the internal resistance was vanishingly small compared with the external resistance, yet heat has been evolved or absorbed in the interior of the cell, and it follows from the law of the conservation of energy that the heat of reaction Q is equal to the electrical energy E, minus the heat q absorbed in the cell.

$$E - q = Q$$

$$E = Q + q \tag{1}$$

q can have a positive value or a negative value, according to whether heat was absorbed or evolved in the cell. If we consider one electro-chemical equivalent involved in the

transformation and measure Q and q in electrical units, then $E = Q + q$ where E measures the E.M.F. in volts. V. Helmholtz investigated the relation which q has to E by applying the second law of thermodynamics. The following reasoning is similar: We know that the mechanical energy of a perfect engine working between the temperature limits $T + d\,T$ and T is

$$d\,W = q\,\frac{d\,T}{T}$$

$$q = T\,\frac{d\,W}{d\,T} \tag{2}$$

Now, since the second law of thermodynamics holds for the transformation of heat-energy into any other form of energy, it must be true for the transformations occurring in a galvanic cell. Now, as mentioned above, the E.M.F. of a cell measures the energy, if we consider the amount of transformation effected by one electro-chemical equivalent, *i. e.*, the work done by the passage of one coulomb. We can, therefore, substitute $d\,E$ for $d\,W$ and we have by substituting $d\,E$ in (2)

$$q = T\,\frac{d\,E}{d\,T} \tag{3}$$

and, therefore,

$$E = Q + T\,\frac{d\,E}{d\,T} \tag{4}$$

$$\frac{d\,E}{d\,T}$$

is the temperature coefficient, and it follows that if the E.M.F. of a cell increases with temperature

$$T\,\frac{d\,E}{d\,T}$$

is positive, and the E.M.F. is larger than the value calculated from the heat of transformation, and heat is absorbed in the cell; whereas, if the E.M.F. decreases with temperature, the E.M.F. is smaller than the value Q expressed in electrical units. Heat is evolved in the interior of the cell. Now, in some primary cells the temperature coeffi-

cient is so small that it can be practically neglected; in others, it is so great that the E.M.F. as calculated from the heat of formation will give a decidedly wrong value. With a reaction that is so different from those utilized in ordinary cells, and concerning which we know so little as the one utilized by Dr. Borchers, it is not legitimate to form any conclusions as to the E.M.F. obtainable.

The question now presents itself, what is then the maximum E.M.F. we can expect to gain from the combination of carbon monoxide with oxygen? Is there any reversible transformation, no matter into what kind of energy, about which we do know something? There *is* such an ideal process, and I will show the reasoning by which we can arrive at the desired value. The reasoning is based on the principle of the dynamical equilibrium of chemical systems, which principle is nothing else than a disguised form of the second law of thermodynamics. When carbon monoxide combines with oxygen, not all of it is thus oxidized, and at a definite temperature and pressure the composition of the resultant mixture of gases, consisting of CO_2, CO and O_2, is definite. Deville found experimentally that at a temperature of 3,000° Celsius forty per cent. of the carbonic acid is dissociated at atmospheric pressure. I have calculated from this fact that at a temperature of 0° Celsius and atmospheric pressure, the fraction of dissociated CO_2 is

$$\frac{1\cdot58}{10^{34\cdot180}}$$

If we conduct the process of combination of CO and O in such a manner that the maximum amount is being obtained, and take care that the temperature does not change, then this work depends on the initial and final condition of the gases. Now, let us suppose 2 gram molecules of carbon monoxide, *i. e.*, 56 grams at atmospheric pressure, react on 1 gram molecule, *i. e.*, 32 grams of oxygen, also at atmospheric pressure, in a reversible manner, and that the carbonic acid formed is likewise brought to atmospheric pressure. Then, evidently, since, as we have seen the dissociation of the carbonic acid is extremely small, the partial

pressure of the carbon monoxide in the product of the reaction must also be very small, and the carbon monoxide, while performing work, has been brought from the atmospheric pressure to an exceedingly small pressure. Now, if the partial pressure of the CO be p_1 then the work done is

$$W = 2\,RT\,log_e \frac{1}{p_1},$$

where R is the gas constant referring to 1 gram molecule of gas and is equal to 1·98 calories. The oxygen is similarly brought from the atmospheric pressure to a partial pressure, which is one-half of the partial pressure of the carbonic oxide; for the gases being present in the ratios in which they react on each other, two volumes of CO are present to one molecule of oxygen, and the pressure of the carbonic oxide is twice that of the oxygen. Hence, the work performed by the oxygen is

$$RT\,log_e \frac{2}{p_1}.$$

Since the carbonic acid in the reaction mixture is practically under atmospheric pressure, no work appreciably is done upon it, and the total energy obtained by the reversible combination of the two molecules of CO with 1 gram molecule of oxygen is

$$W = 2\,RT\,log_e \frac{1}{p_1} + RT\,log_e \frac{2}{p_1}$$

$$W = \quad RT\,log_e \frac{2}{p_1^3}. \tag{5}$$

Since now the fraction of the CO_2 that is dissociated at 0° Celsius is

$$\frac{1{\cdot}58}{10^{34{\cdot}86}}$$

it follows that the partial pressure p of the CO is

$$\frac{1{\cdot}58}{10^{34{\cdot}86}}$$

atmospheres. Substituting this value in equation (5) we have

$$W = RT\,log_e \frac{10^{104{\cdot}58}}{2}.$$

This energy refers to the chemical combination of 2 gram molecules, and is expressed in calories. To obtain the energy for the combination of one electro-chemical equivalent, expressed in electrical units, we divide by 4×23039, and we have

$$E = \frac{1{\cdot}98 \times 273}{4 \times 23039} \log_e \frac{10^{101{\cdot}28}}{2} \text{ volts.}$$

$$E = 1{\cdot}41 \text{ volts.}$$

This is the value for 0° Celsius. The heat of formation of carbonic acid is 68000, and the E.M.F. calculated from this is 1·476. Therefore, by the equation of v. Helmholtz,

$$1{\cdot}41 = 1{\cdot}476 + 273 \frac{dE}{dT}$$

$$\frac{dE}{dT} = -\frac{0{\cdot}066}{273}.$$

The E.M.F. therefore decreases by

$$\frac{0{\cdot}066}{273}$$

volts, with every increase of temperature by 1°. At the standard temperature, 18° Celsius, the E.M.F. is, therefore,

$$1{\cdot}476 - 291 \frac{0{\cdot}066}{273}$$

$$1{\cdot}476 - 0{\cdot}07 = 1{\cdot}406.$$

We thus see that the E.M.F. is somewhat smaller than assumed by Dr. Borchers. The greatest E.M.F. obtained by Dr. Borchers was 0·5 volts. The conclusion which he now draws from this result is that he has already succeeded in obtaining about thirty per cent. of the energy of the coal, whereas, the steam engine converted much less. This is another non-admissible conclusion. For, in an unpolarizable, *i. e.*, reversible, cell, the maximum E.M.F. is a definite value, and if another value is experimentally observed which very appreciably differs from it, then, barring secondary actions, the reaction which is expected to furnish the electric energy does *not* occur. To say that secondary actions depress the theoretical E.M.F. is not logical in this case, for,

evidently, this secondary E.M.F. would have to be about twice as great as the observed E.M.F., and, therefore, could not be called secondary.

The action that took place in Dr. Borchers' apparatus is most probably one that can be found among those which were investigated and published by Mr. Mond (see London *Electrician*, January 11th, and *Digest Electrical World*, New York, February 2d). It would lead too far to discuss in detail the work of Mond, and to single out the particular action to which the E.M.F. of the apparatus of Dr. Borchers was due.

For reasons which were well stated by the latter, it is more expedient and apparently easier to utilize the combination of carbon monoxide with oxygen for the generation of electric energy instead of that of carbon with oxygen. The work done by Dr. Borchers, though not crowned with success as yet, is, nevertheless, of high value on account of its instructiveness. It indicates in its general features the path that has to be followed for accomplishing a most important industrial task, the fulfillment of which we hope this century will yet witness.

DYNAMO AND MOTOR DESIGN.*

By Gano S. Dunn.

The methods of rating electrical machinery are imperfect, and are less definite than in almost any other class. This is because the factors which limit the load of motors and dynamos are several, and their relations are not generally understood.

A machine has a sparking limit to its load, as well as a heating limit, neither of which limits must be exceeded. What the rating should be will, therefore, be dependent upon the character of the duty. We usually designate a dynamo, or motor, as of a capacity of so many kilowatts or

* Abstract of lecture delivered before the Electrical Section of the Franklin Institute, October 23, 1894.

horse-power respectively. Let us take a motor which, on all-day work, could not deliver more than ten horse-power without overheating; and let us assume that its sparking limit would not be reached until it was loaded to thirty horse-power, which load it could carry for periods of three minutes out of every ten throughout the day.

Now, is this a ten or a thirty horse-power motor? It depends upon the work. It is a thirty horse-power elevator or railway motor. It is a ten horse-power motor for running a printing shop by shafting.

These facts control the design of the machine, and it is my purpose to show how they affect the various proportions.

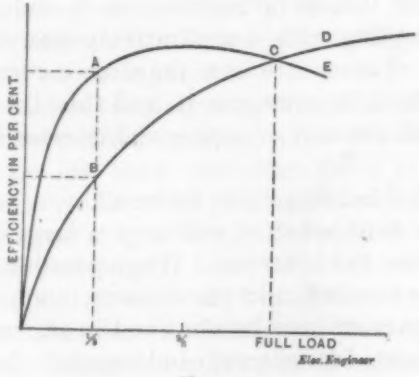

FIG. 1.

In *Fig. 1* are shown the efficiency curves of the two types of machine. These curves differ because of the different distribution of the losses in the machine. Curve *A* represents the efficiency of the continuous running motor, and *B* represents that of the motor whose load is intermittent and excessive. The motor *A* has small fixed losses, such as hysteresis, bearing and brush friction, field current, and comparatively large variable losses, *i. e.*, those which increase with the load, such as the loss due to armature resistance and to commutation.

With motor *B* the reverse is true. The losses in both motors are equal at *C*, but at no other point of the load.

Motor *A* is characterized by a high light load efficiency,

while motor *B* is not. On the other hand, motor *B* never runs at light load, while motor *A* almost always does, as has been found by actual statistics. Readings taken on over 200 motors on commercial circuits showed that these did not average one-third of the rated capacity stamped on their name-plates. The high light load efficiency in motor *A* is of the highest importance, even though it allows the motor to spark if much overloaded; while the ability to stand intermittent, excessive overload, is of the highest importance in motor *B*, even if it is the cause of a low efficiency at light loads, at which, it must be remembered, the motor almost never runs.

Fixed losses are kept low by having a comparatively small amount of iron in armature, which reduces the hysteresis, and winding with comparatively many turns. The small amount of armature iron requires a correspondingly small field circuit to energize it, and this, in turn, a comparatively small amount of copper and current to create the magnetism.

The shaft and bearings may be small.

The type of field selected will have a large influence on one of the losses—field current. When possible, consequent poles should be avoided, and particularly in small machines. The same magnetism can be obtained in salient poles with forty-one per cent. less current and copper. In a comparatively large machine, when the field current is only about one per cent. of the total input, reducing this forty-one per cent. does not affect the efficiency of machine very much; but in a small machine, when field current is, say, ten per cent. of input, reducing by the above amount makes a large difference. The figures of one per cent. and ten per cent. above assumed are the proportions at full load. At one-fourth load they would become four per cent. and forty per cent. respectively, and at this point the advantage of salient poles would be more than ever felt.

The early Edison practice, in which the field magnets were made of many limbs in multiple, was a step in exactly the wrong direction.

Field energy is to be kept low by using coils of circular,

instead of rectangular, section. It takes thirteen per cent. less copper and current to energize magnets of circular, than of square, section. It is advisable, in some cases, particularly in large machines, to use the square or rectangular coil. Rectangular coils are great favorites in England, even in the smaller machines. Elliptical sections are means between the rectangular and circular.

Another feature which keeps the magnetizing field current at a low value, is the selection of a type of field which has a minimum of magnetic leakage. Such fields are those which have their coils in greatest proximity to the armature, and directly facing, or even surrounding it, as in the Eickemeyer machine. In a machine with large leakage, we have to produce many more lines of force than actually go through the armature. This requires larger magnets and larger coils to energize them.

The material of the magnets affects the efficiency and the cost, as follows: Cast iron fields, at two cents per pound, would cost no less than cast steel fields at four cents per pound, since twice as much of the first will have to be used to carry the same magnetism. The steel is the better, however, because, needing to be of only one-half the cross section, less copper is required to surround it, and, therefore, less current. Another advantage of steel over cast iron is that, because of its reduced cross section, it exposes less surface from which leakage may take place.

The armature gives design to every feature of the machine. It may be of heavy core with light winding, or *vice versa*, to meet the conditions of *B* and *A* respectively. The use of multipolar machines has brought out many forms of winding. Two circuit windings are those which, although there be more than two poles to the machine, are so applied that there are but two electrical paths between the brushes. This insures that, should all the poles not be of equal strength, there will be no local action between the circuits within the armature. A form of winding coming into more general use is what is known as a double winding. Its purpose is to give a large number of sections to the commutator in places where it is necessary to use but

few turns in the armature, to secure the proper voltage. As machines increase in size, fewer turns are required to produce a given voltage until the number becomes so small that the number of bars between brushes is so small that the potential between the bars exceeds a safe limit, about twenty volts. We overcome this difficulty by the use of a double winding, shown in *Fig. 2.* An armature is wound with two separate and distinct windings, each of the proper number of turns to give the desired voltage, and the corresponding number of commutator bars, too few to be used by themselves. When these two windings are in conjunction, however, and the bars of one winding alternate with those of the other, we secure, as a result, the voltage desired, with double the number of sections to the commutator. Each winding contributes one-half the current, and the

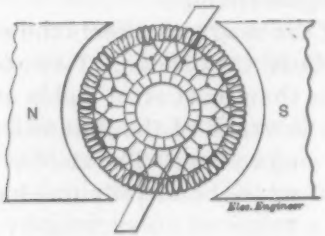

FIG. 2.

brushes, covering at least two bars, are always in contact with both windings.

The sparking of armatures is due usually to the failure of the coil, short-circuited by the brush, to properly reverse its current to make itself ready to take its place in circuit with the rest of the coils after it has left the brush. This reversal of the current may be caused by resistance in the brush, or it may be caused by an E.M.F. established in the coil by causing the moment of short circuit to take place when the coil is under the tip of one of the pole pieces, this being brought about by shifting the brushes. To design a sparkless machine is to take care that the magnetism at the pole tip is not driven away by the reaction of the armature. This reaction is formed by several components, negative ampère turns on the armature and cross-magnetizing ten-

dency, and the knowledge of how to estimate these is what characterizes the designing of to-day from that of the early builders.

As a device (which I have originated) affecting the design of compound-wound dynamos, I would call your attention to the use of a series shunt, whose resistance varies with temperature and the load of the machine. Dynamos which are over-compounded are not worked with full strength of

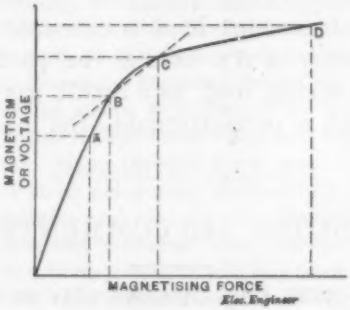

FIG. 3.

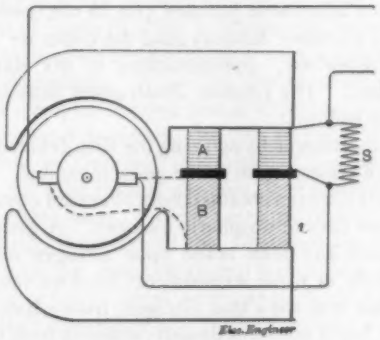

FIG. 4.

magnetism, because it is necessary to have the increase of magnetism, which does the compounding, proportional to the load which needs the compounding, and, at or near full strength, the magnetism of iron is not proportional to the magnetizing force. For this reason the part of the saturation curve from *A* to *B*, *Fig. 3*, is used, instead of the part above *B*. This working at lower saturation reduces the output of the machine.

The part of the curve between *B* and *C* may be used by employing the device shown in *Fig. 4*. *S* is a shunt to the series coils of the dynamo, and it is made of iron or some metal of high temperature coefficient, and may be thermally insulated by a vacuum or by covering with tape. Now, as the load comes on the machine, the current in the series coil *A* does not increase in proportion to it, but faster, because the shunt *S* heats up and throws a greater portion of the current into *A*.

This excess of current in *A* compensates for the diminishing permeability of the iron at the part of the curve on which we are working, and, as a result, gives an increase of magnetism which is proportional to the load of the machine.

NOTES AND COMMENTS.*

"ARGON," THE NEW GAS DISCOVERED BY LORD RAYLEIGH AND PROFESSOR RAMSAY.

A large audience assembled January 31st, in the theatre of the University of London, to hear Professor Ramsay read the paper on "Argon, a New Constituent of the Atmosphere," communicated to the Royal Society by Lord Rayleigh and himself. The London *Times* gives substantially the following account of the proceedings:

The meeting was noteworthy as being the first devoted to the discussion of a single subject and thrown open to the general public. In a former paper it had been shown that nitrogen obtained from chemical compounds is about one-half per cent. lighter than atmospheric nitrogen. A great many experiments were described which had been made upon nitrogen obtained from various sources. The details of these experiments have no interest for the general public, but the result is to show that nitrogen, from whatever chemical source it may be derived, has a constant density, differing from the density of atmospheric nitrogen by a constant quantity. In whatever way the atmospheric nitrogen may be separated the result is the same, and it was to solve the interesting problem thus presented that Lord Rayleigh and Professor Ramsay embarked upon the laborious experiments which have led to the discovery of a hitherto unrecognised substance. As that substance exists in great quantity in the atmosphere, it is decidedly singular that it has been so long overlooked, and all the more so when we consider that it was undoubtedly isolated by Cavendish, although neither he nor those who have followed him observed the significance of the irreducible gaseous residue from his classical

* From the Secretary's monthly reports.

experiment. When the discrepancy in weights between chemical and atmospheric nitrogen was first encountered, attempts were naturally made to explain it by contamination with known impurities, but finally it became clear that the difference could not be accounted for by the presence of any known impurity.

By considerations drawn from the ratio of specific heats, the authors are led to regard argon as a monatomic gas like mercury, and its atomic weight is, therefore, not 20, but 40. The substance is thus removed from among electro-negative bodies like fluorine, where its density would seem to locate it, to a place among such metallic bodies as potassium and calcium. This gets rid of a serious difficulty, but involves the hardly less formidable one of grouping it with such apparently dissimilar bodies as those just mentioned. In this dilemma the authors are almost disposed to regard argon as a mixture of two unknown elements. However, balancing arguments for and against, they seem, on the whole, to incline to the belief that argon is a single element; but the conclusions which follow are, they admit, of a somewhat startling character. Many attempts have been made to induce it to combine, but they have all as yet proved abortive. In dealing with a substance of so absolutely inert and exceptional a character speculation must necessarily proceed upon rather abstract lines. So far as we have reached at present, argon stands entirely unrelated with any other substance in nature, and every theory of its constitution must accordingly be accepted with extreme caution. As to its physical properties, we have a little more information. Its solubility in water is relatively high, being two and one-half times as great as that of nitrogen. Its spectroscopic examination has been conducted by Mr. Crookes, who contributed a supplementary paper dealing with that portion of the subject. It has two distinct spectra, as has nitrogen itself. But while the nitrogen spectra are of different characters, one being a line and the other a band spectrum, the two spectra of argon are of the same type. According to Professor Olszewski, of Cracow, the critical point of the new gas is —121°; the critical pressure, 50·6 atmospheres; the boiling point, —187°; the melting point, —189·6°, and the density of the liquid, 1·5.

Professor Armstrong, President of the Chemical Society, said that the case for the existence of the new constituent was strong, though it had not been brought forward in such logical order as it might have been. There was a body of evidence that there is in the atmosphere a constituent which has long been overlooked. Nitrogen was regarded as a very inert form of matter, and, apparently, argon was like it, only more so. Conceivably it was diatomic; the atoms might be so firmly connected as to take no notice of anything but each other. The spectroscopic evidence did not justify the conclusion that argon is a mixture of two gases—a point upon which Mr. Crookes evidently wavered.

Professor Rucker, President of the Physical Society, said that beyond all question a new constituent of the atmosphere had been discovered.

Lord Rayleigh observed that, though not unaccustomed to difficult investigations, he had never had a harder task than that which he had carried through with the assistance of Professor Ramsay. He discussed shortly the

evidence which seemed to him and his colleague to lend high probability to the belief that the new substance resembles mercury in being monatomic. He found it difficult to conceive how two atoms could be so intimately combined as to suit a diatomic theory of its constitution, but did not deal with the difficulties involved in supposing it monatomic.

Lord Kelvin joined the Presidents of the Chemical and Physical Societies in congratulating the authors on the brilliant success of their investigations.

THE DISCOVERY OF HELIUM.

In a communication to the London Chemical Society, March 27th, Prof. W. Ramsay says: In seeking a clue to compounds of argon, I was led to repeat experiments of Hillebrand on cleveite,* which, as is known, when boiled with weak sulphuric acid, gives off a gas hitherto supposed to be nitrogen. This gas proved to be almost free from nitrogen; its spectrum in a Pflucker's tube showed all the prominent argon lines, and, in addition, a brilliant line close to, but not coinciding with, the D lines of sodium. There are, moreover, a number of other lines, of which one in the green-blue is especially prominent. Atmospheric argon shows, besides, three lines in the violet which are not to be seen, or, if present, are excessively feeble, in the spectrum of the gas from cleveite. This suggests that atmospheric argon contains, besides argon, some other gas which has as yet not been separated, and which may possibly account for the anomalous position of argon in its numerical relations with other elements. Mr. Crookes has identified the yellow line with that of the solar element to which the name "helium" has been given. Mr. Crookes thus stated that he had been enabled to examine spectroscopically two Pflucker tubes filled with some of the gas obtained from the rare mineral cleveite. The nitrogen had been removed by "sparking." On looking at the spectrum, by far the most prominent line was seen to be a brilliant yellow one apparently occupying the position of the sodium lines. Examination with high powers showed, however, that the line remained rigorously single when the sodium lines would be widely separated. On throwing sodium light into the spectroscope simultaneously with that from the new gas, the spectrum of the latter was seen to consist almost entirely of a bright yellow line, a little to the more refrangible side of the sodium lines, and separated from them by a space a little wider than twice that separating the two sodium components from each other. It appeared as bright and as sharp as D_1 and D_2. Careful measurements gave its wave-length 587·45, the wave-lengths of the sodium lines being D_1 589·51, and D_2 588·91. The spectrum of the gas is, therefore, that of the hypothetical element helium, or D_3, the wave-length of which is given by Angstrom as 587·49, and by Cornu as 587·46.

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*Cleveite is a variety of uraninite, chiefly a uranate of uranyle, lead and the rare earths. It contains about thirteen per cent. of the rare earths, and about 2·5 per cent. of a gas said to be nitrogen.

USEFUL FORMULÆ.

According to *Le Genie Civil*, the Munck process for the *manufacture of artificial whalebone* consists in first treating a raw hide with sulphide of sodium and then removing the hair; following this, the hide is immersed for a period of twenty-four to thirty-six hours in a weak solution of double sulphate of potassium, and is then stretched upon a frame or table, in order that it may not contract upon drying. The desiccation is allowed to proceed slowly in broad daylight, and the hide is then exposed to a temperature of from 50° to 60°; the influence of the light, combined with the action of the double sulphate of potassium absorbed by the skin, renders the gelatin insoluble in water and prevents putrefaction, the moisture, moreover, being completely expelled.

Thus prepared, the skin is submitted to strong pressure, which gives to it almost the hardness and elasticity which characterize the genuine whalebone, with the advantage that before or after the process of desiccation any color desired may be imparted to it by means of a dye-bath. The material can be rendered still further resistent to moisture by simply coating it with rubber, varnish, lac, or other analogous substance.

A simplified process for *silvering glass* is thus described by MM. Auguste and Louis Lumière, in the *Journal de Physique*. Take 100 parts by volume of a ten per cent. solution of nitrate of silver, and add, drop by drop, a quantity of ammonia, just sufficient to dissolve the precipitate formed, avoiding any excess of ammonia. Make up the volume of the solution to ten times the amount by adding distilled water. The reducing solution used is the formaldehyde of commerce. The forty per cent. solution is diluted to a one per cent. solution. The glass to be silvered is polished with chamois leather, and the bath is made up immediately before use, by mixing two parts by volume of the silver solution with one of formaldehyde. The solution must be poured over the surface without stopping. After the lapse of five or ten minutes, at a temperature between 15° and 19° C., all the silver in the solution will be found to have been deposited on the glass in a bright layer, which is then washed in running water. It is then varnished, if the glass side is to be used; or polished, if the free surface is required for reflection. This method does not require the scrupulous care necessary with other methods.

Apropos to formaldehyde, the *Scientific American* reports an interesting application of the substance, which may prove of some value in photography. This is the discovery that formaldehyde has the property of *rendering gelatine insoluble in water*. Gelatine, both in solution and in the dry condition, is said to be rendered insoluble by formic aldehyde, and the jelly after treatment becomes non-fusible. When a very small proportion of formaldehyde is mixed with a warm solution of gelatine, the whole sets on cooling, but can be remelted. If, however, the jelly be spread out and allowed to dry, the gelatine becomes completely insoluble in water, forming a flexible film, which can be used for photographic negative purposes. In both the wet and dry collodion processes, chrome-gelatine is used to insure the adhesion of the collodion to the glass plate, the sensitised collodion

emulsion being poured on to the thin layer of chrome-gelatine previously applied. Instead of chrome-gelatine, formaldehyde-gelatine can be used, but whether with advantage remains to be seen. The applications of formaldehyde-gelatine are patented to A. Zimmerman, London,* and a process for making sensitive films is described in the specification.

When nitrocellulose, dissolved in alcohol and ether, or in soda or potash-soluble glass, is spread over a surface of wood, paper, glass, porcelain, or metal, and the solvent allowed to evaporate, the film remaining is said to have the appearance of *mother-of-pearl*. The proportions recommended are: 1 part of nitrocellulose; 78 parts of alcohol (90 to 100 per cent); 21 parts of ether. With soluble glass as the solvent, 10 parts of this to 90 parts of water are employed.

The nitrocellulose may be pure or crude, or in different stages of nitrification, as gun-cotton, etc. Ethyl or methyl alcohol, and sulphuric or acetic ether, are recommended. The degree of concentration of the nitrocellulose may be varied within certain limits, which variations produce different results. The addition of bisulphide of carbon in the proportion of 25 parts to 100 of the above solution, or the addition of benzine, produces a difference in the brilliancy and arrangement of the colors of the iris developed on the mother-of-pearl-like surface.

The best *cleansing compound for nickel ware* is 50 parts of alcohol and one of sulphuric acid. The article to be cleaned is held in the solution five to fifteen seconds, after which it is washed with water, rinsed with alcohol and wiped dry with a clean rag.

From the *Scientific American*, we learn that Mr. B. Haskell, superintendent of motive-power on the Chicago and West Michigan, and the Detroit, Lansing and Northern Railway, is using *burlap for packing* tender and engine truck boxes. The material is the burlap or sacking that the baled waste is wrapped in. The material is springy and will not mat. Its elasticity keeps it up in contact with the journal and its texture permits the oil to pass through it freely. The material is cut up quite fine preparatory to use. Mr. Haskell writes to *Railway Engineering and Mechanics*, that he finds it to be equally as good as woollen waste, and has the advantage of costing nothing. He furnishes his trainmen with saturated waste instead of oil for oiling cars. To prepare this waste he has built a special tank. It is circular and will hold about six barrels of oil. A coil of steam pipe is run around the inside of the tank, and a shelf of stack netting is secured on one side. About two barrels of oil are turned into the tank and waste enough to absorb that quantity of oil. Steam is then turned on and the oil heated slightly, making it thin enough to be absorbed readily by the waste. It is then allowed to soak for at least twenty-four hours, and, after being again heated, the waste is put on the shelf to drip. The second heating is to make the waste drip more quickly than it otherwise would. A little experience in heating the oil will enable the operator to prepare it so that the oil will drain from the waste without any handling or pressing. It has been found so con-

* British Patent, No. 2036, 1894.

venient that since the plan has been adopted the trainmen are not given oil, but saturated waste instead, and the cost of oiling cars has been greatly reduced thereby.

Cobalt nitrate is found by Dr. Johann Antal, a Hungarian chemist, to be an *antidote in prussic acid and cyanide poisoning*. After having demonstrated its value by experiments on animals, the author administered it to no less than forty persons who had been accidentally poisoned by prussic acid, and in all cases the results are reported to have been satisfactory.

PRODUCTION OF BESSEMER STEEL INGOTS AND RAILS IN 1894.

The Bulletin of the American Iron and Steel Association prints complete statistics of the production of Bessemer steel ingots and of Bessemer steel rails of all weights and sections in the United States in 1894, including a small quantity of standard rails, and a larger quantity of street and electric rails, which were made by manufacturers from purchased blooms. In the statistics of ingots produced are included the production of the few Clapp-Griffiths and Robert-Bessemer plants, and also the production of steel castings by all Bessemer works.

The total production of Bessemer steel ingots in 1894 was 3,579,101 gross tons, against 3,215,686 gross tons in 1893, showing an increase in 1894 of 363,415 tons, or 11·3 per cent.

The total production of all kinds of Bessemer steel rails, including light and heavy, and street and mine rails, in the United States in 1894 was 1,014,034 gross tons, against 1,129,400 gross tons in 1893, a decrease in 1894 of 115,366 gross tons, or 10·2 per cent. The production of Bessemer steel rails in 1894 was composed of 899,120 gross tons rolled by the producers of domestic ingots, and 114,914 tons rolled from purchased blooms.

PIG IRON AT $5.00 PER TON.

An illustration of the claims made for Southern manufacturing locations is seen in a recent statement given out by a company of Northern and Western capitalists who have been investing largely in East Tennessee lands. This statement is to the effect that the La Follette Coal and Iron Company has about 50,000 acres of land, on which are some fifteen or twenty seams of bituminous coal lying horizontally one above the other. This company also owns 7,000 or 8,000 acres of iron ore land, which runs from fifty-four to fifty-nine per cent. metallic iron. The coking coal and the iron ore are said to be within the extremes of half a mile, and between the two is an unlimited quantity of limestone, the three being so situated that they can be delivered at the furnaces by gravity, without the use of steam. The gentleman making these statements predicts that pig iron of a quality sufficient to make basic steel will be produced at this point within a period of eighteen months, at a cost not to exceed $5 00 per ton.

This is the lowest figure yet mentioned as the cost of producing Southern pig iron. Within the past year it has been stated that pig iron was being

made with washed coke at a total cost of $5.99 per ton, in the Birmingham, Ala., district. A journal devoted to Southern manufacturing interests said at that time that the cost in the Birmingham district had been cut down to less than $6.50, a reduction of $3.00 per ton from the lowest figures reached six or seven years previous. A later estimate placed the figures at $6.37. At various times Southern pig iron has been put into this market at figures which, if there was anything in the trade, would put the cost of production even below $5.00 per ton, but such sales have always been under peculiar circumstances. We are inclined to think that even with the great natural advantages claimed by the company mentioned, $5.00 pig iron will hardly be produced in the near future.—*American Manufacturer.*

THE BALTIC AND NORTH SEA CANAL.

During the latter part of June it is expected that the canal connecting the Baltic and North Seas will be opened for commerce.

The line of the canal starts at Kiel, on the Baltic Sea, and crossing the Prussian Province at Holstein, joins the Elbe at Brunsbuttel, below Hamburg. Work was begun on June 3, 1887, and over 8,600 men were employed during the summer months, while in winter the number was reduced to about 4,700. The plant comprised 90 locomotives, 2,473 cars, 66 dredgers, 133 lighters and 55 engines. The estimated cost was M 156,000,000 ($37,440,000), and the thoroughness of preparation and efficiency of execution cannot be better illustrated than by mentioning the fact that the estimate has not been exceeded.

There will be two locks: one at the Baltic end, open all the year round, except during 25 days; and one on the Elbe, open three to four hours during every flood tide, so that it may almost be termed a tidewater canal. Its length is 53½ miles; average depth, 29½ feet; width at bottom, 72 feet; width at water level, 213 feet.

At Brunsbuttel, on the Elbe, there is an outer harbor 1,312 feet long by 328 feet wide; then follows the lock, 492 feet by 82 feet and 32⅔ feet deep, and then an inner harbor 1,640 feet by 656 feet. Two suspension bridges cross the canal nearly 138 feet above water level, so that railway traffic will not be interrupted.

The speed allowed on the canal will be 5·3 miles per hour, making the time of passage about thirteen hours. The toll will be 75 pfennigs, or 18 cents per net register ton (loading capacity). It is expected that about 18,000 ships will make use of the canal annually, representing about 7,500,000 tons. Hitherto about 35,000 ships passed every year through the Skager Rack and the Cattegat, between the Baltic and the North Sea, so that the estimated percentage seems fair. The saving of time will be considerable, since for all ships bound to or from any point south of Hull the distance will be reduced by 238 miles, while Bremen ships will save 322 miles and Hamburg ships 424 miles. But more important than the saving in time is the avoidance of danger, the passage through the Sound between the Scandinavian Peninsula and Jutland being considered one of the most dangerous in

Europe. Statistics show that about 200 vessels founder every year on these coasts.

The strategic value of the canal is, beside, of the greatest value to Germany, because its men-of-war will be able to pass from the North Sea to the Baltic with ease and safety, avoiding the passage through foreign waters, and permitting rapid concentration on the North or the West coast.—*Engineering and Mining Journal.*

OUR TIN-PLATE CAPACITY.

Secretary John Jarrett, of the Tinned Plate Manufacturers' Association, publishes a statement concerning our tin-plate industry. It appears from the statement that when the tin-plate mills under construction and those projected are finished and running, the output of tin-plates in this country will be over half a million boxes above the present annual consumption of tin-plates in the United States. The annual consumption is given at about 6,000,000 boxes, which includes the tin-plates exported by the Standard Oil Company and the various canneries. The capacity of mills built and building is given at 4,980,000 boxes annually. If those projected are built, Mr. Jarrett says that the output would be 6,720,000 boxes. But we annually export about 1,500,000 boxes in the form of cans of all sizes, and if it be assumed that this part of our supply is always to be obtained abroad, then our strictly domestic consumption is reduced, according to Mr. Jarrett, to about 4,500,000 boxes.

By examination of the Treasury statistics we find that the imports of tin-plates during the four fiscal years ended June 30, 1890, amounted to 2,623,006,255 pounds, or an average of 655,751,564 pounds per year, equivalent to 6,557,516 boxes of 100 pounds each. As no tin-plates were made in this country during the years mentioned, the domestic consumption is practically represented by the imports for the period. During the four fiscal years ended June 30, 1894, the imports of tin-plates amounted to 2,541,251,204 pounds, and the domestic production in the three years ended June 30, 1894, as ascertained by the Treasury Department, was 252,689,388 pounds, making the total available supply during the four years 2,793,940,592 pounds, or 27,939,406 boxes. This gives an average annual supply of 698,485,148 pounds, or 6,984,851 boxes during the past four fiscal years. For the past eight years the average annual supply of tin-plates has been 6,771,183 boxes, and this practically represents the average yearly consumption during that period.

It will be observed that Mr. Jarrett's figures of the annual consumption of tin-plates in this country, including the export trade, are too low by from half a million to a million boxes. It should also be seriously taken into account that many of the prospective tin-plate works mentioned by Mr. Jarrett may never be built. Besides, it is almost too much to expect that all the works actually constructed will annually work up to their full capacity. We have no doubt that eventually we will have the capacity to produce more tin-plates than we can consume, but it is too soon, in our opinion, to assume that this result has been reached, or that it is dangerously near.

We concede, however, that if we are always to obtain abroad the tin-plates that we export in various ways, because these tin-plates may be obtained virtually free of duty owing to the drawback provision of the tariff, then our capacity to produce tin-plates is already near the actual home consumption. But why assume that exported tin-plates will continue to be made abroad?—*Bull. Iron and Steel Association.*

BOOK NOTICES.

Electric Transmission of Energy and its Transformation, Subdivision and Distribution. A practical handbook. By Gisbert Kapp. (4th edition, thoroughly revised.) New York: D. Van Nostrand Company. 1894.

Those of our readers who are interested in electrical science will be so familiar with the previous editions of this excellent handbook, that no introduction will be required in making reference to the appearance of a 4th edition.

In this the author has been compelled, by the enormous strides that have taken place in connection with electric power-transmission since the appearance of the previous editions, to modify considerably the scope of the work. The historical portion of the subject has accordingly been entirely omitted, as has likewise the detailed description of a number of transmission plants.

On the other hand, the present edition devotes considerably more space to the theory of continuous current machines, while the theory of alternators and multiphasers has been added. W.

Annuaire pour l'An 1895, publié par le Bureau des Longitudes; avec des notices scientifiques. (Price, fcs. 1.50.) Paris: Gauthier-Villars et fils. 1895.

This publication, issued annually by the "Bureau des Longitudes," contains, in conveniently accessible form, all the information that would naturally be looked for in a nautical almanac, together with a large amount of miscellaneous information respecting the coinage, statistics, geography, mineralogy, chemistry, etc. Among the specially interesting communications contained therein is one by Berthelot, giving a series of thermo-chemical values revised and corrected to date. W.

The Source and Mode of Solar Energy.—By I. W. Heysinger, M.D. Philadelphia: J. B. Lippincott Company. 1895.

The above-named work is an ingenious speculation in which the author seeks to account for the origin and maintenance of the solar energy. Like others who have preceded him in the study of this fascinating problem, notably Meyer and Sir Wm. Siemens, the author finds the explanation in sources exterior to the sun. His views on the subject are interesting and forcibly presented, and the book will repay perusal. W.

A Laboratory Manual of Physics and Applied Electricity.—Arranged and edited by Edward L. Nichols, Professor of Physics in Cornell University. In two volumes. Vol. II. Senior courses and outlines of advanced work. By George S. Moler, Fred'k Bedell, Homer J. Hotchkiss, Chas. P. Matthews, and the Editor. New York: Macmillan & Co. 1894. Price, $3 25.

This is the companion volume to the manual for beginners in physics, which was lately reviewed in these columns, and is intended for the guidance and instruction of advanced students, who are prepared to undertake special work.

The book is divided into four parts, viz.: Experiments with direct current apparatus; experiments with alternating currents; senior courses on heat and photometry; and outlines of advanced work in general physics. The first three parts have been prepared with especial reference to the needs of those who are preparing themselves for the profession of electrical engineer. The method followed in the work is the presentation of experimental studies of the most important problems occurring under each chapter head. W.

Encyclopédie Scientifique des Aide-Mémoire. Paris: Gauthier-Villars et fils. (Price, per vol., fcs. 2.50, unb.; fcs. 3, bound.)

The following additional volumes of this practical and comprehensive encyclopædia of the arts and manufactures have been issued since the publication of the previous reference thereto in this *Journal.*

Dudebout et Croneau. Ingénieurs de la Marine. *Appareils accessoires des chaudières à vapeur.*

Leloutre, Georges. Ingénieur civil. *Le Fonctionnement des Machines à vapeur.*

Hatt. Ingénieur hydrographe de la Marine. *Des Marées.*

Vallier. Chef d'escadron d'Artillerie, Correspondant de l'Institut. *Balistique des nouvelles poudres.*

Jacquet, Louis. Ingénieur des Arts et Manufactures. *La fabrication des eaux-de-vie.*

La Baume Pluvinel, A. de. *La Théorie des procédés photographiques.*

Bourlet, C. Professeur au Lycée Henri IV, Docteur ès Sciences. *Traité des Bicycles et des Bicyclettes, suivi d'une application à la Construction des Vélodromes.*

Sorel, E. Ancien ingénieur des manufactures de l'État. Professeur suppléant au Conservatoire des Arts et Métiers. *La Distillation.*

The foregoing volumes are uniform in appearance, each forming a small octavo, and complete in itself. Each subject is treated by a competent specialist. The convenient form of the separate parts of the series, and the condensed yet thorough treatment which each subject receives, render this work an extremely useful one. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, April 17, 1895.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1895.

Mr. JOS. M. WILSON, President, in the chair.

Present, seventy-two members and thirteen visitors.

Additions to membership since last report, nine.

The paper of the evening was read by Mr. E. D. Smith, on the Chicago Drainage Canal.

The speaker gave an account of the general scope of this important work, and of its salient engineering features; also, of the methods employed in its construction, the present state of the work, etc. The paper was profusely illustrated by means of lantern views made from photographs taken on the scene of operations. It was discussed by the author, Prof. Lewis M. Haupt, Messrs. Spencer Fullerton, G. M. Eldridge, Warner Walter, the President, the Secretary and others.

On Mr. Fullerton's motion, the thanks of the meeting were voted to Mr. Smith for his interesting and instructive presentation of the subject.

The Secretary, in his monthly report, gave a description, with the aid of a view upon the screen, of the new steel cantilever bridge about to be built over East River at Blackwell's Island, New York. (A brief account of this structure appears in the annual report of the Secretary, published in the February impression of the *Journal*.) He also gave a brief account of a number of important ship canals, either under construction or projected, in Europe and America.

The Secretary referred also to the fact that the evidence, which Lord Rayleigh and Professor Ramsay had succeeded in accumulating in demonstration of the existence of "argon," the alleged new constituent of the atmosphere, is now believed to be so convincing, that the genuineness of the discovery may beregarded as having been placed beyond doubt. He referred also to the probable identification, by Professor Ramsay, of "helium"—ahypothetical element heretofore believed to exist only in the sun—in a mineral of terrestrial occurrence.

Of new inventions, there were presented and described, an under-surface conduit system for electric trolley railways, devised by Mr. Joshua M. Hammill; and a trolley-car fender, invented by Mr. Frederick Fiechter.

Adjourned.

WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

T. F. TOWNSEND, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MARCH, 1895.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 31, 1895.

GENERAL REVIEW.

The average temperature for March, 1895, 33°·8, is 1°·5 below the average [35°·3] for the past seven years.

The highest recorded temperatures occurred on the 1st, 24th, 25th and 31st, and were as follows: Coatesville, 70°; Uniontown, 68°; Lancaster, 67°; Pottstown, 67°, and Lycippus, 67°.

The lowest were on the 3d, 5th, 14th and 15th: Wellsboro, minus 4°; Smethport, 1°; Shingle House, 1°; and Edinboro, 1°.

At the close of the month, grain and grass appear to have wintered well, but all vegetation is backward, with but few signs of spring.

From January 1, 1895, to March 31, 1895, the accumulated deficiency in daily mean temperature at Philadelphia was 328°; at Erie, 419°, and at Pittsburgh, 483°.

For the same period the deficiency in precipitation, in inches, at Philadelphia, was 1·23; Erie 3·40, and at Pittsburgh, 3·08.

TEMPERATURE.

	Mean Temperature.	*Mean Precipitation, Inches.*
March, 1888, ...	31°·1	3·55
1889, ...	38°·9	2·90
1890, ...	33°·4	5·15
1891, ...	34°·1	5·10
1892, ...	32°·0	4·14
1893, ...	34°·7	2·52
1894, ...	43°·2	1·63
1895, ...	33°·8	2·31

The means of the daily maximum and minimum temperatures, 42°·9 and 24°·8, respectively, give a monthly mean of 33°·8, which is 9°·4 below the corresponding month of 1894.

The average daily range was 18°·1.

Highest monthly mean, 39°·3 at *Philadelphia* [Centennial Avenue].

Lowest monthly mean, 26°·6 at Le Roy and Wellsboro.

Highest temperature recorded during the month, 70° on the 1st at Coatesville.

Lowest temperature, minus 4° on the 3d at Wellsboro.

Greatest local monthly range, 63° at Shingle House.

Least local monthly range, 40° at South Bethlehem.

Greatest daily range, 55° at Drifton.

PRECIPITATION.

The average precipitation for the State, for the month, 2·31 inches, is 1·26 inches less than the average [3·57] for the past seven years.

General snows occurred on the 2d, 9th, 11th, 12th, 15th and 16th, but they were mostly light and without drift. Most of the snow remaining on ground at the end of the month, was the remains of the heavy drifts in February.

The heaviest snowfall totals in inches for the month were: Cassandria, 22·0; Somerset, 20·5; Wellsboro, 18·0, and Salem Corners, 12·6.

The largest totals of rainfall and melted snow in inches were: Confluence, 4·03; Uniontown, 3·86; Carlisle, 3·67; Stoyestown, 3·66; Phœnixville, 3·61; Pottstown, 3·57, and Forks of Neshaminy, 3·51.

The least were: Elwood Junction, 0·99; State College, 1·03; Altoona, 1·05; Saegerstown, 1·14; Williamsport, 1·16, and Towanda, 1·28.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 11; clear days, 10; fair days, 10; cloudy days, 11.

BAROMETER.

The mean pressure for the month, 30·04, is about ·02 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·65 at Harrisburg on the 23d, and the lowest 29·44 at Erie on the 1st.

MISCELLANEOUS PHENOMENA.

Thunderstorms.—Hollidaysburg, 25th, 26th; Le Roy, 25th; Towanda, 25th; Quakertown, 25th; Cassandria, 25th, 27th; Emporium, 25th; East Mauch Chunk, 25th; State College, 27th; West Chester, 25th; Coatesville, 25th; Kennett Square, 25th; Phœnixville, 25th; Lock Haven, 25th, 27th; Uniontown, 27th; Huntingdon, 25th; Coopersburg, 25th; Williamsport, 8th, 25th, 31st; Smethport, 25th; Pottstown, 25th; South Bethlehem, 25th; Easton, 25th; Logania, 9th, 25th; Selins Grove, 9th, 25th, 27th, 28th; Somerset, 25th, 27th; Wellsboro, 25th; Lewisburg, 24th, 28th, 31st; Dyberry, 25th; Hamlinton, 25th; South Eaton, 25th.

Hail.—Gettysburg, 15th; Towanda, 30th; Kennett Square, 9th, 15th; Phœnixville, 14th, 15th; Wilkes-Barre, 30th; South Bethlehem, 15th; Logania, 25th; Blooming Grove, 30th; Selins Grove, 28th; Dyberry, 13th, 15th; Honesdale, 30th; Hamlinton, 15th; York, 15th.

Snow.—Gettysburg, 2d, 11th, 15th, 16th; Hamburg, 2d, 9th, 11th, 12th; Hollidaysburg, 2d, 11th, 12th, 15th, 16th, 18th, 24th; Le Roy, 2d, 4th, 6th, 9th, 15th, 26th, 27th; Towanda, 2d, 6th, 15th, 26th; Quakertown, 2d, 15th, 16th; Cassandria, 2d, 6th, 9th, 12th, 14th, 15th, 16th, 17th, 18th, 26th; Emporium, 2d, 4th, 6th, 7th, 9th, 15th, 16th, 24th; East Mauch Chunk, 3d, 9th, 12th, 15th, 16th; State College, 2d, 9th, 15th, 16th, 18th, 24th; West Chester, 11th; Coatesville, 2d, 9th, 11th, 15th, 16th; Kennett Square, 1st, 11th, 15th; Phœnixville, 2d, 11th, 15th; Grampian, 2d, 4th, 6th, 7th, 9th, 12th, 15th, 16th, 24th; Lock Haven, 2d, 6th, 9th, 13th, 14th, 15th, 16th, 24th; Carlisle, 11th, 15th, 16th, 24th; Uniontown, 2d, 8th, 16th; Huntingdon, 2d, 11th, 15th, 24th; Lancaster, 2d, 11th, 12th, 13th, 14th, 15th, 16th; Lebanon, 2d, 9th, 11th, 12th, 15th, 16th, 24th; Coopersburg, 2d, 9th, 15th, 16th; White Haven, 2d, 7th, 9th, 28th; Wilkes-Barre, 2d, 9th, 12th, 15th; Williamsport, 2d, 6th, 8th, 16th; Smethport, 4th, 6th, 7th, 16th, 24th, 26th; Pottstown, 2d, 9th, 11th, 14th, 15th; South Bethlehem, 2d, 9th, 12th, 15th, 16th; Easton, 2d, 9th, 16th; Logania, 2d, 9th, 11th, 14th, 15th, 24th; *Philadelphia* [Centennial Avenue], 2d, 9th, 11th, 15th, 26th; Blooming Grove, 2d, 6th; Shingle House, 4th, 6th, 7th, 15th, 24th, 25th, 26th, 27th; Selins Grove, 2d, 9th, 12th, 15th, 16th; Somerset, 2d, 8th, 10th, 14th, 15th, 17th, 18th, 24th, 26th; Wellsboro, 2d, 4th, 6th, 9th, 11th, 15th; Lewisburg, 2d, 9th, 11th, 15th, 16th, 24th; Dyberry, 2d, 4th, 6th, 12th, 13th, 15th, 26th, 28th; Honesdale, 2d, 6th, 12th, 15th, 26th; Hamlinton, 2d, 4th, 6th, 9th, 12th, 15th, 16th, 24th, 26th; Lycippus, 2d, 8th, 9th, 15th, 18th, 27th; South Eaton, 2d, 9th, 15th; York, 2d, 9th, 11th, 15th, 16th, 24th, 26th.

Sleet.—Gettysburg, 15th, 24th; Hollidaysburg, 15th; Towanda, 30th; Quakertown, 2d, 15th, 30th; Coatesville, 15th; Kennett Square, 12th, 15th; Lock Haven, 4th; Huntingdon, 15th; Lancaster, 15th; Lebanon, 25th; Coopersburg, 15th; White Haven, 15th; Easton, 15th; Logania, 9th, 14th, 15th, 29th; *Philadelphia* [Centennial Avenue], 2d, 15th, 29th; Selins Grove, 15th; Dyberry, 13th, 15th; Honesdale, 12th, 13th.

Coronæ.—Towanda, 3d, 8th.

Solar Halo.—Philadelphia [Weather Bureau], 27th; [Centennial Avenue], 21st, 24th, 27th; Wellsboro, 20th.

Lunar Halo.—Towanda, 3d.

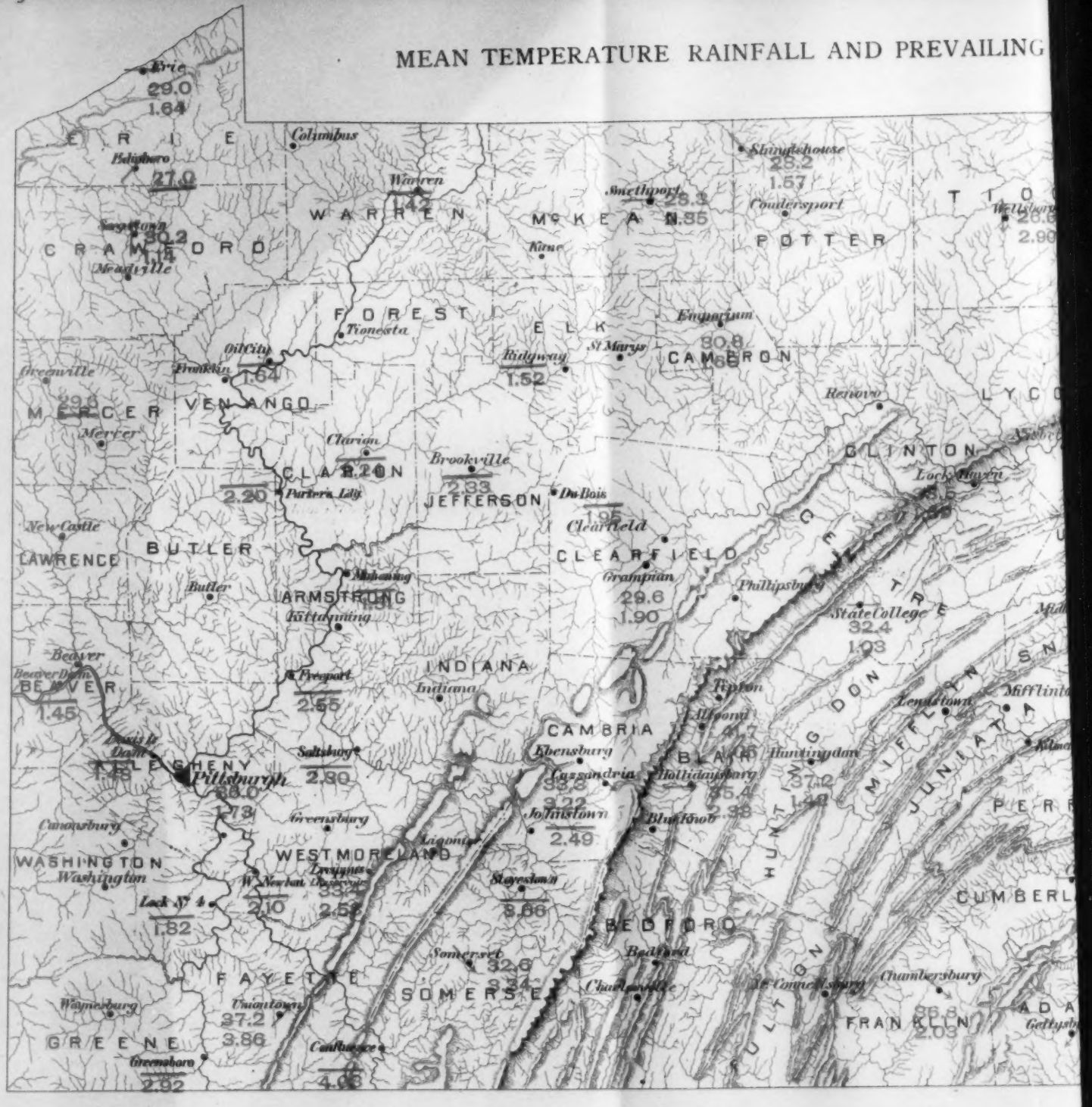
Parhelias.—Le Roy, 31st; Towanda, 11th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for March, 1895.

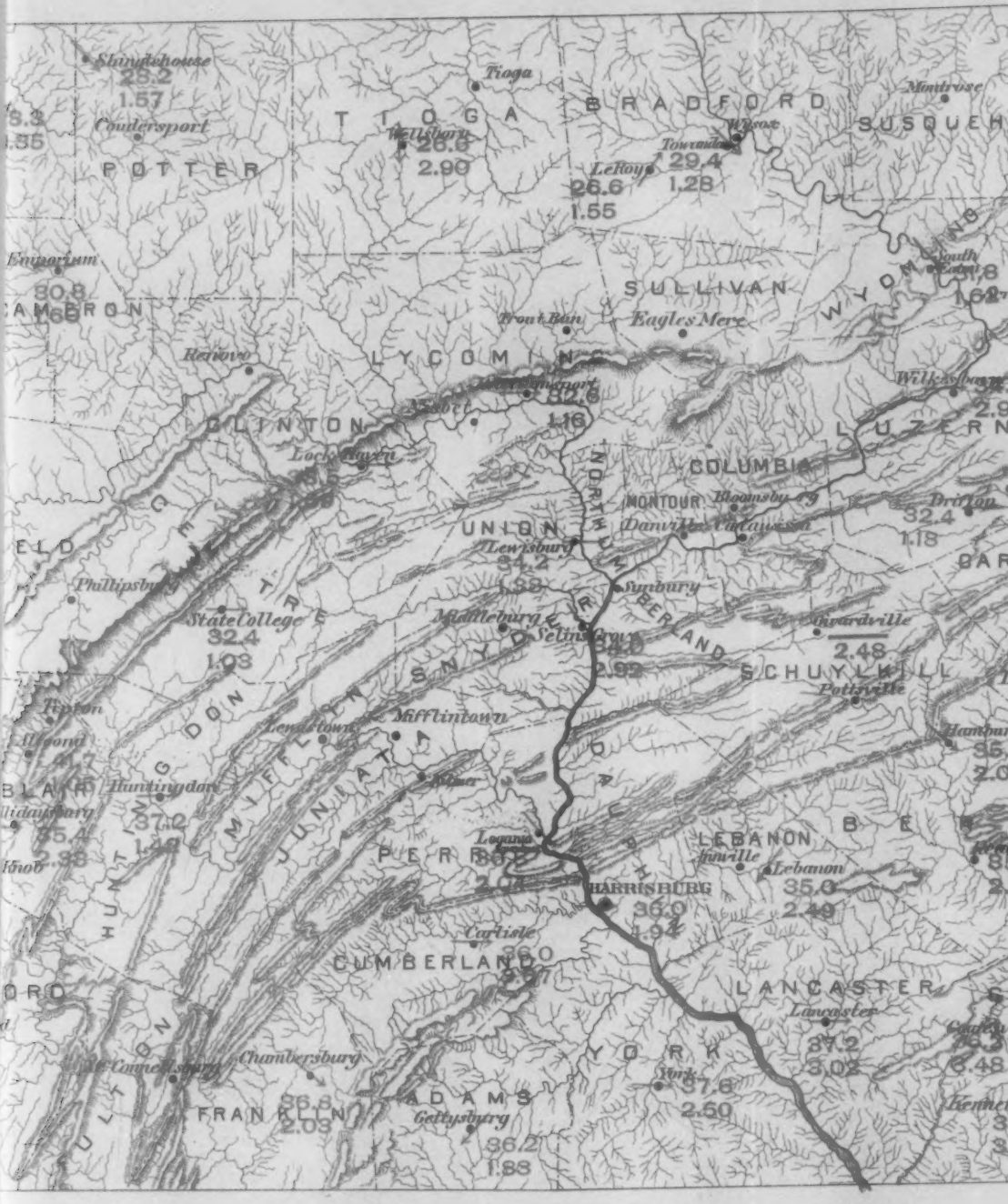
County.	Station	Elevation above Sea Level (feet).	Temperature.									Precipitation.				Number of Days.			Wind. Prevailing Direction.	Observers
			Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range.		Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rain or Snow.	Clear.	Fair.	Cloudy.		
				Highest.	Date.	Lowest.	Date.			Mean.	Greatest.									
Adams,	Gettysburg,		36·2	61	25	18	5	44·3	28·0	16·3	33	1·83	6·0	. .	10	14	9	8	NE	H. F. Buehler.
Allegheny,	Pittsburgh,	820	36·0	63	31	16	5, 14	42·2	27·6	14·6	31	1·73	7·6	. .	15	7	14	10	NW	O. D. Stewart, W. B
Berks,	Hamburg,	380	35·0	59	1	13	5	43·1	26·9	16·2	30	2·05	7·5	. .	10	5	14	12	NW	William Shipe.
Berks,	Reading,[2]	280	35·4	. . .	. .	. . .	. .	. . .	. . .	. . .	. .	2·19	. . .	. .	14	. .	. .	. .	. . .	Franklin Yager.
Blair,	Altoona,	1,181	41·7	63	2	24	16	50·1	33·3	16·8	27	1·05	. . .	. .	12	. .	. .	. .	. . .	Dr. C. B. Dudley.
Blair,	Hollidaysburg,	947	35·4	63	24	13	5	46·4	24·4	22·0	34	2·33	12·2	. .	12	14	3	14	W	Prof. J. A. Stewart.
Bradford,	Le Roy,	1,400	26·6	51	1	5	5, 15	34·2	19·0	15·2	30	1·55	8·7	. .	13	7	11	13	SW	G. W. T. Warburton.
Bradford,	Towanda,	754	29·4	54	1	3	3	37·0	21·7	15·3	41	1·88	7·0	. .	8	12	7	12	NW	Hiram E. Bull.
Bucks,	Forks of Neshaminy,[1]	304	39·0	. .	. .	. .	. .	. .	. .	. .	. .	3·51	. . .	. .	12	19	. .	12	N	J. C. Hilsman.
Bucks,	Quakertown,	536	34·0	62	1	13	5	42·4	25·7	16·7	31	2·70	7·5	. .	13	7	17	7	NW	J. L. Heacock.
Cambria,	Cassandria	2,100	33·3	55	24	12	3, 5	40·1	26·5	13·6	30	3·22	22·0	3·0	16	9	9	13	NW	A. H. Boyle.
Cambria,	Johnstown,†	1,184	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	E. C. Lorentz.
Cameron,	Emporium,	1,050	30·8	55	24	5	5	40·7	21·0	19·7	35	1·60	10·6	. .	10	9	13	9	E	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	33·0	62	1	11	5	42·1	24·0	18·1	37	2·53	7·5	. .	11	15	4	12	E	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Sta.,	1,191	32·4	57	25	11	5	40·9	23·9	17·0	30	1·03	10·3	. .	11	9	6	16	W	Prof. Wm. Frear.
Chester,	West Chester,	455	37·0	63	1	15	5	45·8	28·3	17·5	29	3·44	3·8	. .	14	17	4	10	W	J. C. Green, D.D.S.
Chester,	Coatesville,	380	36·2	70	1	17	5	46·5	25·8	20·7	40	3·48	10·0	. .	11	12	12	7	W	W. T. Gordon.
Chester	Kennett Square,	275	38·2	66	1	18	5	48·5	28·0	20·5	33	3·48	2·0	. .	12	10	7	14	N	B. P. Kirk.
Chester,	Phœnixville,	190	37·3	66	1	18	15	46·1	28·5	17·6	29	3·61	5·0	. .	13	7	6	18	NW	Knowles Croskey.
Chester,	Westtown,‡	350	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	John D. Carter.
Clearfield,	Grampian,	1,450	29·6	54	24	6	5	37·6	21·5	16·1	32	1·90	17·0	. .	15	5	13	13	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	33·5	58	24	. . .	. .	. . .	. . .	. . .	. .	1·69	14·5	. .	12	10	7	14	W	Prof. J. A. Robb.
Crawford,	Saegerstown,	1,200	30·2	59	31	2	14	41·9	18·5	23·4	40	1·14	. . .	. .	5	8	7	16	S	J. G. Apple.
Cumberland,	Carlisle (30 days),	480	36·0	62	25	18	3	44·8	27·3	17·5	30	3·67	8·0	. .	11	14	5	11	W	J. E. Pague.
Dauphin,	Harrisburg,	480	36·0	58	25	17	3	43·0	29·0	14·0	24	1·94	. .	. .	13	11	8	12	W	F. Ridgway, W. B.
Delaware,	Swarthmore— Swarthmore College,‡	361	. . .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	Prof. S. J. Cunningham.
Erie,	Edinboro,*[1]	190	27·0	62	24	1	14	. . .	. . .	. . .	. .	. .	3·0	. .	. .	. .	. .	. .	SW	C. F. Sweet.
Erie,	Erie,	1,400	29·0	60	24	2	14	38·0	21·0	17·0	30	1·64	. . .	. .	10	7	11	13	W	P. Wood, W. B.
Fayette,	Uniontown,	681	37·2	68	29	18	3, 9	45·3	25·0	16·3	41	3·86	11·0	. .	14	12	10	9	SW	Wm. Hunt.
Franklin,	Chambersburg,	1,000	36·8	62	25	19	5	46·5	27·1	19·4	34	2·03	. . .	. .	11	8	9	14	NW	J. C. Boggs.
Huntingdon,	Huntingdon— The Normal College,	650	37·2	62	24	10	3	47·9	26·6	21·3	37	1·42	9·0	. . .	7	1	27	3	W	Prof. W. J. Swigart.
Lancaster,	Lancaster— Franklin and Marshall Col'ge,	413	37·2	67	1	17	5	46·7	27·7	13·0	32	3·02	8·7	. . .	14	13	12	6	W	A. V. Heister.
Lebanon,	Lebanon,	458	35·0	. . .	. .	15	5	‖ 43·3	26·6	16·7	. .	2·49	10·3	. . .	12	14	11	6	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	35·4	59	1	14	5	43·7	27·0	16·7	31	2·60	8·1	. . .	13	13	12	6	NW	Dr. M. H. Boye.
Luzerne,	Drifton (26 days),	1,683	32·4	64	1	5	4	44·5	20·3	24·2	55	1·18	10·8	0·5	7	9	8	9	E	J. R. Wagner.
Luzerne,	White Haven,			57	2	8	5	39·4	21·4	18·0	31	1·79	11·0	. . .	10	7	15	9	N	C. M. Driggs.
Luzerne,	Wilkes-Barre,	575	34·0	59	23	10	3	44·2	23·7	20·5	34	2·95	11·5	. . .	8	12	9	10	W	A. W. Betterly.
Lycoming,	Williamsport,		31·6	56	25	10	5	39·9	25·2	14·7	27.	1·16	6·8	. . .	10	10	11	10	W	G. D. Snyder, C. E.
McKean,	Smethport,	1,500	28·3	57	25	1	5	38·1	18·5	19·6	39	2·35	10·5	. . .	10	11	9	11	W	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	29·6	53	25	6	14	38·9	20·2	18·7	28	. . .	. . .	. . .	. . .	22	2	7	. .	Prof. S. H. Miller.
Montgomery,	Pottstown,	150	37·7	67	1	17	5	45·8	29·6	16·2	32	3·57	11·0	. .	11	13	11	7	NW	Charles Moore, D.D.S.
Northampton,	South Bethlehem,	339	34·8	55	25	15	5	43·0	26·7	16·3	29	. . .	6·5	. .	. .	10	10	11	NW	T. Merriman.
Northampton,	Easton— Lafayette College,	325	34·8	56	1	11	5	43·3	26·2	17·1	30	2·16	4·8	. . .	11	11	8	12	. .	J. W. Moore.
Perry,	(Aqueduct) Logania,	367	36·8	62	25	19	5, 19	45·4	28·3	17·1	30	2·04	6·5	. . .	12	11	11	9	NW	Richard Callin.
Philadelphia,	U. S. Weather Bureau	117	38·1	64	1	18	5	45·7	30·5	15·2	28	2·61	3·8	. . .	12	13	7	11	NW	L. M. Dey, W. B
Philadelphia,	1529 Centennial Avenue,	120	39·3	62	1	20	5, 15	48·0	30·6	17·4	28	3·24	5·0	. .	12	13	8	10	NW	John Comly.
Pike,	Blooming Grove,*[1]		30·6	57	1	7	5	. . .	. . .	. . .	. .	1·47	4·0	. .	9	. .	27	4	S	John Grathwohl.
Potter,	Shingle House,	1,475	28·2	64	30	1	7	39·6	16·8	22·8	46	1·57	6·8	. . .	10	16	7	8	NW	H. L. Pearsall.
Snyder,	Selins Grove,	455	34·0	58	25	11	3	44·5	23·6	20·9	37	2·92	9·0	. . .	11	. .	17	14	NW	J. M. Boyer.
Somerset,	Somerset,	2,250	32·6	65	25	5	17	44·2	21·1	23·1	40	3·34	20·5	. . .	11	4	18	9	NW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	26·6	45	1, 31	—4	3	. . .	. . .	. . .	. .	2·90	18·0	. . .	10	3	10	18	N	H. D. Deming
Union,	Lewisburg	450	34·2	59	25	12	5	43·2	25·1	18·1	33	1·38	8·2	. .	10	11	10	10	W	Prof. W. G. Owen.
Wayne,	Dyberry,	1,100	27·4	55	1	5	3, 6	37·6	17·1	20·5	35	1·44	11·0	9·0	10	13	4	14	NW	Theodore Day.
Wayne,	Honesdale,	1,000	30·4	56	1	8	6	38·4	22·4	16·0	32	1·51	6·5	. .	15	10	11	10	NW	Andrew Thompson
Wayne,	(Salem Corners) Hamlinton,	1,600	29·4	55	1	4	5	37·4	21·5	15·9	34	1·91	12·6	8·0	13	8	11	12	NW	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	33·4	67	30	14	5, 9	43·0	23·7	19·3	41	2·53	10·8	. .	11	. .	. .	. .	. .	Murray Forbes.
Wyoming,	South Eaton,	660	31·8	55	1	5	3	41·2	22·4	18·8	37	1·62	7·0	. . .	9	10	9	12	NW	B. M. Hall.
York,	York,	385	37·6	66	1	18	5	47·1	28·2	18·9	32	2·50	10·8	. . .	13	11	10	10	W	Mrs. L. H. Grenewa'd.

Mean temperature from maximum and minimum readings. * Extremes from dry thermometers [1] Mean temperatures, 7 + 2 + 9 + 9 + 4 [2] Mean temperature 8 + 8 + 2.
† No records. ‡ Records incomplete. ‖ 24 days.

MEAN TEMPERATURE RAINFALL AND PREVAILING



RAINFALL AND PREVAILING WIND DIRECTION FOR MARCH, 189



Montrose
SUSQUEHANNA
WAYNE
27.4
1.44
Duberry
Honesdale
30.4
1.51
Scranton
Bloomingrove
30.8
1.47
Milford
PIKE
Wilkesbarre
32.0
2.95
LUZERNE
White Haven
MONROE
Stroudsburg
Drifton
32.4
1.18
30.4
1.79
BARBON
Mauch Chunk
33.0
2.58
NORTHAMPTON
Easton
34.8
2.16
Lynnport
Bethlehem
LEHIGH
Allentown
Hamburg
35.0
2.05
Kutztown
Dunkertown
34.0
BUCKS
Doylestown
2.77
Reading
85.4
2.19
MONTGOMERY
Pottstown
37.7
3.57
Norristown
Hilltown
Phoenixville
CHESTER
Coatesville
West Chester
Bristol
38.1
2.61
Kennett Square
38.2
3.46
DELAWARE
PHILADELPHIA